HUMPBACK WHALES AND HUMANS: A MULTI-DISCIPLINARY APPROACH TO EXPLORING THE WHALE-WATCHING INDUSTRY IN JUNEAU, ALASKA

By

Suzanne Teerlink

A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of

Doctor of Philosophy

in

Marine Biology

University of Alaska Fairbanks

May 2017

APPROVED:

Larissa Horstmann, Committee Chair

Briana Witteveen, Committee Member

Franz Mueter, Committee Member

Doug DeMaster. Committee Member

Anne Beaudreau, Committee Member

Sarah Hardy, Chair

Department of Marine Biology

S. Bradley Moran, Dean

College of Fisheries and Ocean Sciences

Michael Castellini, *Dean of the Graduate School*

Abstract

A booming whale-watching industry in Juneau, Alaska is leading to complicated resource management challenges. Juneau's growing commercial whale-watching industry includes over 60 vessels and generates more than $25 million in annual revenue. As this industry has increased, so too have concerns for the welfare of humpback whales (*Megaptera novaeangliae*) exposed to this vessel traffic. However, we lack a fundamental understanding of long-term impacts, if any, that vessel disturbance has on humpback whales. Further, we have insufficient data on local abundance and seasonal attendance of humpback whales that are necessary to detect potential future changes. The aim of this project is to investigate Juneau area humpback whales and their interactions with whale-watching tourism to set a foundation for sustainable management of this resource and industry. To reach this objective, three studies were employed. 1) Methods for monitoring humpback whale population parameters through a citizen science program were developed and tested. Photo-identification data were collected on whale-watching platforms and compared to data from dedicated surveys to objectively evaluate the citizen science data collection methods and identify biases. 2) Physiological markers were evaluated for signs of a chronic stress response in blubber of Juneau-area humpback whales compared with humpback whales from other areas in Alaska with far less vessel traffic. The concentrations of several steroid hormones, including cortisol, were measured from biopsy samples and used to infer a relative cumulative stress response in whales exposed to Juneau's tourism fleet. 3) Community perceptions toward Juneau's whale-watching industry and humpback whale management were collated to consider stakeholder concerns and suggestions for local humpback whale management. Participants were given the opportunity to share their perspectives on humpback whale welfare, community considerations and concerns, and recent and proposed management changes that affect the whale-watching industry. I found that citizen science data can produce reliable estimates of abundance, especially with sufficient effort. I did not find evidence for increased stress response in Juneau-area humpback whales and argue that this indicates habituation in these animals. Respondents in our survey generally supported Juneau's whale-watching industry, but expressed concerns for the vessel crowding and the welfare of humpback whales in this area. This project combines multiple scientific disciplines to tackle the initial steps necessary in understanding the complex interaction between humans and humpback whales near Juneau, and in making management decisions that ensure a sustainable future for Juneau's humpback whales and the whale-watching industry that relies on them.

Table of Contents

List of Figures

Page

List of Tables

Page

Acknowledgements

This project was only possible because of the dozens of people who contributed time, resources, interest, skills, and ideas. I would like to thank my committee chair, Lara Horstmann, for her mentoring and advising. Lara was my number one cheerleader. She provided challenge when I needed challenge and encouragement when I needed encouragement. Each and every interaction we had made this project better and helped me to be a better scientist and writer. I am also hugely grateful to my committee, who each brought something unique and essential to the table. Franz Mueter was an incredible help with statistical testing and his perspective on study design. Anne Beaudreau was essential in helping me to successfully introduce the social science methods to the project, and offered several ideas that helped to clarify and improve the project. Bree Witteveen was critical as a humpback whale expert and for teaching me biopsy field techniques. Doug DeMaster was fantastic in his ability to offer a broader perspective and push me to see how my work fit into the policy framework.

Thank-you to my many professors and mentors who shared their wealth of knowledge with me. Thank-you to Ginny Eckert and the National Science Foundation/Marine Sustainability in the Arctic and Subarctic (MESAS) IGERT program for the additional training, guidance, and opportunities beyond a normal Ph.D. program. Thank you to the North Pacific Research Board (G8728) and the NSF MESAS IGERT (Award #DGE-0801720) for financial support.

My field-work was only possible because of the volunteers who joined me in collecting data. Thank-you Leif Short-Forrer, Megan Peterson, Kelli Anderson, Karson Coutre, Ben Williams, Paul Williams, Karen Teerlink, Steve Teerlink, Jessica Glass, Heidi Pearson, Kaili Jackson, Melissa Rhodes-Reece, Vanessa Hernandez, Ed Lyman, Carley Lowe, Jennifer Teerlink, Liz Tobin, Tyler Thomas, Bryce Mecum, and Kelly Cates. I am grateful to Amber Jannasch and the Purdue University Bindley Bioscience Center, Patrick Charapata and Nichole Farnham for their assistance with laboratory analyses.

I am grateful to have the opportunity to work with such a diverse group of stakeholders and collaborators. Thank-you to the industry participants who worked closely with me to collect data, share ideas, and brainstorm solutions, in particular, Bob Janes, Sierra Gadaire, Scott Ranger, Julia Frances and Liz Stahl. Thank-you to Sanjay Pyare, Jan Straley, Aleria Jensen, Heidi Pearson, and Shannon Atkinson for their professional expertise and advice. Thank-you to those that offered guidance forming the questionnaire, including, Sanjay Pyare, Jim Powell, and Brian VanderNaald. Thank-you to Jane Sullivan for endless encouragement and substantial help visualizing data. Thank-you to Gabrielle Hazelton and Karl Wuoti for the above-and-beyond efforts to make the administrative aspects operate smoothly.

Thank-you to my family and friends who offered support and encouragement. My husband, Leif Short-Forrer, for being willing to help with boat driving, maintenance boats, and offering in-home support to allow me to undertake this monumental task.

Thank-you to my dear friends who have been such an inspiration and encouragement, Megan Peterson, Kelli Anderson, Renee Warr, Heather Hardcastle, Jane Sullivan, Aleria Jensen, Jennifer Teerlink, Ellen Chenoweth, Carley Lowe, among others. Thank-you to my parents, Karen Teerlink and Steve Teerlink, who have always been such an incredible support. Thank-you to Eric Forrer and Sally Short for their love and support. Thank-you to Finn Forrer, my son who joined my dissertation process 4-years in, for forcing me to take frequent play, snack, and lego breaks. Lastly, thank-you to all of the dedicated, talented, and hard-working scientists whose work I have built upon and the teachers and professors who are committed to training the next generation of scientists. I am honored to be a small part of this enormous, ongoing effort to better understand this precious and complex world.

General Introduction

Resource management can present enormous challenges. To be effective, it requires resource monitoring, a comprehensive understanding of threats, and consideration for social and economic factors, while simultaneously being adaptable to new information. This can be particularly difficult for wildlife species, where little information is known about the biology, ecology, and potential vulnerabilities of the animals.

In recent decades, wildlife viewing tourism has been increasing in popularity around the world, and management strategies for these industries vary widely. Wildlife viewing is generally considered a non-consumptive use of a publically owned resource, meaning that the “use” of the resource does not preclude others from using it (Hoyt and Parsons 2014). For this reason, many wildlife viewing tourism industries are completely unmanaged, particularly in developing countries (e.g., whale-watching in Sri Lanka; Buultjens et al. 2016). However, wildlife tourism is not always strictly non-consumptive, as it can negatively impact wildlife to the point of limiting the resource. Further, other indirect impacts to the environment or community can make it necessary to manage these industries (Higham et al. 2015). To mitigate these potentially negative outcomes, several wildlife-viewing industries have adopted conservative wildlife management models that limit vessel numbers and/or speed (*e.g.*, Weinberg et al. (2002), Taylor et al. (2011), and Neilson et al. (2016)).

Whale-watching tourism in Juneau, Alaska, is a booming industry that started in 1994 (pers. comm. D. Ward, 2016) and has grown to be one of the largest whale-watching industries in the world. The industry focuses on viewing humpback whales (*Megaptera novaeangliae*), but vessels also stop to watch killer whales (*Orcinus orca*), Steller sea lions (*Eumetopias jubatus*), harbor seals (*Phoca vitulina*), Dall's porpoise (*Phocoenoides dalli*), and bald eagles (*Haliaeetus leucocephalus*). This dissertation is a case study of humpback whales in the Juneau-area in the context of the local whale-watching industry. Here, I attempt to further our social-ecological understanding of humpback whales, the threats to this resource, the industry that relies on them, and the community perceptions around humpback whales and the whale-watching industry.

Study Area

Juneau is located in the inside waters of the Alexander Archipelago of Southeast Alaska. While Juneau is located on the mainland, it has no road access to other communities, making it reliant on barges, ferries, and airlines for transportation and supplies. It is home to over 32,000 year-round residents (United States Census Bureau). Juneau has the highest cruise ship traffic in Alaska with over 1 million passengers per year, all of which occurs from May-September, resulting in dramatic seasonality in tourism activity and the economy (Alaska Department of Commerce, Community, and Economic Development 2012).

Whale-Watching Industry in Juneau

Whale-watching participation in Juneau includes standard wildlife viewing tours and charter fishing tours (whale-watching is typically supplementary to fishing on these tours). Whale-watching is also common among recreational boaters and kayakers, however, the focus of this dissertation is on commercialized wildlife viewing. Dozens of vessels of various sizes participate in Juneau's whale-watching industry, ranging from ~20 meter, 150-passenger platforms to ~8 meter, 6-passenger boats. From an internet search of outfits that advertise whale-watching as part of boat-based tours leaving Juneau's Auke Bay Harbor, I identified a total of 60 different vessels from 15 companies.

Feeding humpback whales are Juneau's main whale-watching attraction. In Alaska, humpback whales primarily feed on small schooling fish, such as Pacific herring (*Clupea pallasii*), and zooplankton, such as euphausiids and copepods (Nemoto 1957; Witteveen et al. 2008). Humpback whales are *rorquals*, a family of baleen whales characterized by longitudinal grooves in the skin that allow for their buccal cavity to expand. This allows for relatively large mouthfuls of water and food, which can then be filtered through the baleen to expel water before the food is swallowed (Johnson and Wolman 1984). Rorqual engulfment is energetically costly, and these whales rely on dense aggregations of prey to make foraging energetically beneficial (Goldbogen et al. 2012). Humpback whales are known to use barriers to condense prey before engulfment. They are often seen pushing prey up against shorelines, deploying bubble curtains, and corralling fish with their long pectoral flippers (Jurasz and Jurasz 1979; Sharpe 2001). This may be one reason why humpback whales are commonly seen in nearshore waters. The main attraction for Juneau whale-watching tours is bubble net feeding by humpback whales, a behavior in which a group (4-20) of humpback whales encircles their prey with rings of bubbles and breaks the surface of the water in unison to engulf their prey (Sharpe 2001; Leighton et al. 2007). This behavior has been increasing in frequency and seasonal duration in the Juneau area, and is now common for approximately three months of the five-month whale-watching season (S. Teerlink, unpublished data).

Compared with other predominant U.S. humpback whale whale-watching industries (*e.g.*, Hawaiian Islands, Stellwagen Bank), vessel activity in Juneau's whale-watching industry is much less distributed. A combination of geography (narrow and obstructed waterways) and whale behavior (frequent aggregation) encourages vessel crowding around whale groups. Therefore, the industry in Juneau is difficult to compare with other humpback whale-focused whale-watching industries that are in more open areas and have more dispersed whale distributions. However, the resident killer whale-watching in the inland waters of Washington State appears to be similar. Washington's inland waters are also constricted by islands, and resident killer whales, which travel in large family pods, are aggregated (Duffus et al. 1993; Trites and Bain 2000; Lusseau et al. 2009). Similar to Juneau, a large number of vessels (commercial and recreational) participate in whale-watching in this area, and vessel crowding is common (Duffus et al. 1993; Lusseau et al. 2009). While the vessel crowding and management challenges in

Washington State are similar to Juneau, the management approach for this industry appears to be further developed. Washington State has an organized whale-watching association, a boater education program (www.whalemuseum.org), 200-yard vessel approach regulations (NOAA 2011), and ongoing research to monitor resident killer whales (*e.g.*, www.whalemuseum.org).

Humpback Whale Conservation

Humpback whales were once considered to be on the brink of extinction from commercial exploitation (Johnson and Wolman 1984), however, they have been recovering throughout much of their range (Calambokidis et al. 2008). Humpback whales are found in most of the world's major oceans. They inhabit high latitudes in summer months, feeding and accumulating energy stores, and they migrate to low latitudes for winter months to birth young and breed (Johnson and Wolman 1984). Humpback whale gestation is approximately 11.5 months, so calves conceived one winter are born the following winter, after a full migration cycle has been completed (Johnson and Wolman 1984; Zerbini et al. 2010). Conservation efforts appear largely successful in the North Pacific Ocean as the population has been increasing at 5-7% in most of this range (Calambokidis et al. 2008).

Humpback whales are protected under the Marine Mammal Protection Act (MMPA), as are all marine mammals in the U.S., and the Endangered Species Act (ESA). Recently (September, 2016), the National Marine Fisheries Service (NMFS) designated humpback whales into 14 distinct population segments (DPSs) for management purposes. While all humpback whales were previously considered endangered (globally) under the ESA, after defining the finer DPS management units, only five out of the 14 DPSs remain listed under the ESA as endangered or threatened (NOAA 2016). Population recovery throughout the majority of the humpback whale range, and the resulting removal of 9 DPSs from the ESA, is celebrated as a conservation success story.

Humpback whales in Southeast Alaska continue to have protection under the ESA and through other regulatory and voluntary measures. The Mexico DPS of humpback whales is listed under the ESA as threatened and occurs in Southeast Alaska, albeit in small numbers (6%; Wade et al. 2016). However, because it is not possible to distinguish Mexico DPS humpback whales from the non-ESA listed Hawaii DPS, which makes up the larger proportion of Southeast Alaska humpback whales (94%; Wade et al. 2016), all Southeast Alaska humpback whales are afforded ESA protection. Humpback whales in Alaska have an additional layer of protection through the Alaska Humpback Whale Approach Regulation, prohibiting boaters from approaching within 100 yards, positioning whales between boats and land, or positioning a boat in the path of a humpback whale, such that they will surface within 100 yards (NOAA 2004). In 2015, the National Marine Fisheries Service (NMFS) and the Whale and Dolphin Conservation (WDC) non-profit launched a voluntary stewardship and recognition program in Juneau called Whale SENSE, standing for **S**tick to the regional whale-watching guidelines, **E**ducate naturalists, captains, and passengers to have SENSE while watching whales, **N**otify appropriate networks of whales in distress, **S**et an example for other boaters, **E**ncourage ocean stewardship. The program was initially developed for whale-watching participants on the U.S. East Coast in 2009, and was adapted to meet the needs of Juneau's whale-watching industry. Participants of this program agree to guidelines for vessel operation and onboard education (www.whalesense.org). The majority of Juneau-based operators currently participate in the Whale SENSE program.

Dissertation Goals

The research presented in this dissertation is a case study of Juneau's humpback whales, and the whale-watching industry that relies on them. I took a broad, interdisciplinary approach to understanding the complex dynamics between humpback whales and humans in the Juneau area. Here, I developed cost-effective tools for monitoring humpback whales through citizen science (Chapter 1), established current baselines of populations parameters (abundance, site fidelity, etc.; Chapter 1), investigated potential negative consequences of vessel disturbance by measuring physiological markers of humpback whale stress response (Chapter 2), detected pregnancy in humpback whales through hormone levels in biopsy samples (Chapter 2), characterized community perceptions toward tourism (Chapter 3), and documented concerns and suggestions of Juneau residents to support a more sustainable local tourism industry (Chapter 3). Through this project, I made a pointed effort to break down the walls between academia and stakeholders to encourage the two to work together to better understand humpback whales and their complex interactions with humans. The methods and conclusions from this study can be broadly useful to study and manage other wildlife resources around the world.

Chapter 1: Validating citizen science data for humpback whale monitoring[1]

Abstract

Humpback whales (*Megaptera novaeangliae*) near Juneau, Alaska are heavily relied upon by the city's booming whale-watching industry. Whale numbers near Juneau have been increasing as humpback whales world-wide recover following cessation of industrial whaling. Consequently, the Endangered Species Act status of humpback whales has changed for many regions around the world. However, we do not fully understand the threats that whale-watching, commercial fishing, and climate change present to the species, or how these factors may impact whales in the Juneau area, making it essential to continue to monitor this population. In this study, we assess citizen science photo-identification data collected from whale-watching vessels during the summers of 2013 and 2014 by comparing it to data obtained from a dedicated weekly survey over the same sampling period. We analyze the datasets by estimating abundance and measures of residency separately and with both datasets combined to illuminate biases specific to the citizen science methodology. Citizen science data produced lower abundance estimates in 2013 when effort was low (similar amount of effort to dedicated surveys) and comparable abundance estimates in 2014 when effort was high (4x the dedicated survey effort). We estimated 72 (95% CI 56 - 91) individuals in 2013 and 85 (95% CI 68 - 107) whales in 2014 using the combined datasets. Estimates of retention in the study area were more biased using citizen science data,

---

[1] Teerlink, S. and L. Horstmann. Validating citizen science data for humpback whale monitoring. Submitted to *PLOS ONE* (*In Review*).

which tended to inflate measures of site fidelity and residency rates and underestimate transience and Lagged Identification Rates. Therefore, measures of residency were best estimated without citizen science data. However, residency estimates from citizen science data may still be valuable as a relative measure. This study demonstrates how citizen science can be a practical method for monitoring humpback whales, while also meeting outreach and education objectives and strengthening our connections to the tourism industry.

Introduction

Citizen science is a process whereby non-scientist volunteers participate in scientific data collection that may otherwise be difficult to obtain. Cetacean data, in particular, can be difficult to collect due to logistical and financial constraints, and the use of opportunistic data collection has been increasing in this field. Citizen science applied to marine-based research often utilizes existing platforms, or platforms of opportunity, to collect data using little or no research funding [1]. For example, there is a growing number of studies that use platforms of opportunity to gather data on cetaceans from ferry boats [2,3], bridges [4], cruise ships [5], and whale-watching vessels [6–11]. Citizen science from platforms of opportunity generally allows for collection of more data than is possible from dedicated surveys, but does not contribute additional vessel disturbance [1].

Citizen science programs have been useful in longitudinal studies of humpback whales (*Megaptera novaeangliae*). Longitudinal and baseline studies, while invaluable to science and management, can be difficult to fund and may be more feasible if volunteer participation is enlisted. This has been demonstrated in two studies. First, a shore-based citizen science effort for humpback whales in Hawaii is aimed at generating a gross point estimate of whales counted on a single day during the peak of the whale season. This effort is called the "Great Whale Count," and has been conducted during most years since 1995 [12]. Second, whale-watching boats in the Gulf of Maine collected extensive photographic sightings of humpback whales from 1979 to 1995, that have been useful in multiple studies of population dynamics (e.g., [13,14]).

A drawback to citizen science data collection is that compromised field methods and inexperienced field assistants can introduce bias in the data collected [1,15]. It is therefore important to consider these biases and make efforts to measure their influence and potentially mitigate them. That said, citizen science data collection can often accommodate much higher sampling effort that, in turn, generates larger quantities of data. Larger sample sizes can often buffer against data bias [15], and in some cases, provide a trade-off where accurate results are possible with increasing sample sizes despite any additional bias introduced by the citizen science-specific field methods (e.g., [16]). Also, it is important to acknowledge that biases are inherent in all cetacean research, including conventional scientific methods, and it may be pragmatic to employ citizen science data in cetacean research once the methodological-specific biases have been considered [1,17–19]. Conversely, there are some added benefits to citizen science programs that also deserve consideration. For instance, citizen science programs have the added advantage of helping to forge valuable partnerships by fostering positive collaboration among scientists, managers, the community, and tour industry. Further, citizen science is useful as an outreach tool and helps to engage non-scientists in the scientific process by giving them first-hand experience with scientific methods [1].

Juneau, located in southeastern Alaska, USA, has become a popular destination for whale-watching tourism, primarily focused on humpback whales. The growing whale-watching industry in Juneau is currently comprised of nearly 60 vessels from more than 12 companies and supports upwards of 250,000 tour passengers per summer season [20]. Humpback whales are seasonally abundant in Alaska, peaking in summer and fall months, and migrate to lower latitudes in winter and spring [21,22]. Humpback whales found in the Juneau area are part of a larger genetic stock with maternally directed site fidelity to southeastern Alaska [23,24].

Juneau area humpback whales are a valuable marine resource to the local tourism industry and are in need of long-term monitoring. Humpback whale abundances worldwide are recovering from past over-exploitation, and numbers have been increasing rapidly throughout the North Pacific Ocean, including southeast Alaska [25]. Further, many Distinct Population Segments (DPSs) of humpback whales are no longer listed under the Endangered Species Act (ESA;[26]), including the Hawaii DPS, which makes up approximately 94% of southeast Alaska’s summer population [27]. The ESA explicitly states the need for post-delisting monitoring to ensure that numbers and productivity do not decline after ESA protections are removed. The humpback whale post-delisting monitoring plan for all DPSs that are no longer listed under the ESA emphasizes the need for long-term monitoring throughout the range of humpback whales, which includes Southeast Alaska for the Hawaii DPS [28]. The Juneau area is particularly in need of monitoring, as the local tourism industry may pose a potential harassment risk to whales in this area, and the industry is also dependent on predictable and consistent presence of humpback whales. Monitoring data will provide managers with baseline parameters specific to this area and make them better able to detect and interpret changes in area use that may unfold due to excessive vessel traffic, changes in climate and prey availability, and/or increases in abundance from continued recovery of humpback whale populations [21].

Prior to this study, there has been no consistent longitudinal study of humpback whales near Juneau. Glacier Bay National Park (GBNP) is a nearby region that is also a popular destination for cruise ship tourism, but has maintained a standardized long-term monitoring program of humpback whales since 1985. This program has tracked humpback whale recovery in GBNP, has led to a comprehensive, multi-decadal understanding of population dynamics, has estimated local life history parameters, and has captured several anomalies in abundance and calving [29]. Managers appear more equipped to interpret fluctuations in abundance in GBNP and make policy decisions that support sustainable tourism than for neighboring Juneau. However, such programs can be difficult to fund, and there are no allocated funds for similar long-term monitoring of humpback whales in the Juneau area.

In this study, we conducted weekly surveys of humpback whales in the Juneau tour area from dedicated research platforms and compared these data to data collected from tour vessels (platforms of opportunity) by volunteer citizen scientists by subjecting them to the same quantitative analyses. This side-by-side comparison allowed us to quantify the biases inherent in the use of tour boats as survey platforms and objectively consider the use of citizen science as an alternative or supplement to dedicated surveys. We also present our suggested estimates of the population parameters (abundance and various measures of residency) for the study area. We predicted that bias from citizen science data would deflate estimates of abundance and inflate measures of residency. While there is unquestionable educational value in engaging the public in the scientific process and forging collaborative industry ties, this is, to our knowledge, the first study to directly validate citizen science data collected by whale-watching vessels. Finding ways to make use of citizen science data for humpback whales, while maintaining scientific rigor, would make it possible to implement a long-term monitoring program with increased field effort and low financial overhead.

Methods

Study Area

The study area (Fig. 1.1) is defined by the Juneau, AK, tour area, a region characterized by a series of islands with complex shorelines and narrow waterways. Typically, Juneau whale-watching tours leave from Auke Bay Harbor and return within 2.5 - 3 hours, giving most whale-watching vessels a maximum range of approximately 40 km from the harbor. Each tour vessel generally operates 2-3 trips per day.

Photo Processing

Photo-identification is a commonly used field method for monitoring humpback whales [30,31]. Photographs of the ventral flukes, as a whale descends on a sounding dive, are taken using a digital camera with a telephoto lens. The unique pigmentation and scarring patterns in combination with shape and trailing edge of the flukes persists over time and can be used to identify individual humpback whales [32]. Figure 1.2 shows an example of a re-sighted individual using photo-identification.

Photographs were cropped and edited with Adobe Lightroom 5, and matched to the Juneau-specific whale fluke catalog (www.juneauflukes.org). Whales that were new to the Juneau catalog were matched to the broader southeast Alaska catalog (www.alaskahumpback.org) by an experienced matcher. Sightings were entered into a database, so that individual sighting histories could be summarized. Photos from each sighting were ranked for quality in 6 categories (contrast/exposure, fluke angle, camera angle, fluke proportion visible, clarity/focus, overall) as in [33], and photos that scored low in the ranking were flagged, so they could be removed from analyses sensitive to heterogeneity. Efforts to assess photo quality independent of fluke recognizability are important to safeguard against biasing the dataset toward more distinct and recognizable whales [31,33].

Dedicated Survey

We conducted weekly surveys of the Juneau tour area in 2013 (June-September) and 2014 (May-September). We attempted to space surveys out to occur every 7 days during the field season, when possible, but weather and other logistical considerations sometimes forced timing between surveys to vary from 2 - 15 days (Table 1.1). During each survey, photo identification was attempted for all humpback whales encountered in the tour area using a 400mm Nikon DSL camera. No set transect was used, but an attempt was made to cover as much of the tour area during each survey as possible. An effort was made to alternate the area prioritized during a survey to avoid repeatedly missing coverage of any part of the study area. Environmental conditions, time, date, GPS location, whale group size and composition, behavior, and number of nearby boats were recorded for each sighting. Surveys were observational in nature and were carried out in strict accordance to protocols approved by the University of Alaska Fairbanks Institutional Animal Care and Use Committee (IACUC, protocol # 474034-1), and under

National Marine Fisheries Service scientific research permit # 14296. Every effort was made to minimize disturbance to whales being approached or photographed for this study.

Citizen Science

Citizen science data were collected onboard whale-watching vessels and through an online photo submission portal (www.juneauflukes.org; created and managed by S. Teerlink). Citizen science surveys did not have research permits, and participants adhered to regular wildlife viewing regulations, including the Alaska humpback whale approach regulations that prohibit vessels from approaching within 100 yards of humpback whales, prohibit operators from positioning vessels in the path of oncoming humpback whales causing them to surface within 100 yards, and require them to operate at slow, safe speeds when near humpback whales [34].

Whale-watching vessel surveys: A single whale-watching tour company, Gastineau Guiding Company, offers a specific “citizen science” tour that highlights scientific methods and gives passengers the opportunity to participate in data collection. We collaborated with Gastineau Guiding Company to collect the majority of our citizen science data. On citizen science tours, guides used a 300mm Canon digital camera to collect fluke photos opportunistically throughout the tour. Tour boats were not working under a scientific research permit that would allow them to maneuver close to whales, and also had additional tour logistics to consider, so the citizen science trips were less focused on collecting data than the dedicated surveys. Environmental conditions, location, group size, and behavior were recorded for each group of whales encountered. Cameras were outfitted with Global Positioning System (GPS) geotagging devices, and camera settings were checked periodically to ensure the time and date stamp in the camera was accurate. This allowed for automating the process of recording time, date, and GPS location by embedding it directly into the metadata of the fluke photo. We met with Gastineau Guiding Company tour guides multiple times throughout the whale-watching season for training and troubleshooting protocols. Data were submitted to us, in aggregate, at the end of each season.

Web portal submissions: Citizen science data submitted through the www.juneauflukes.org website were collected less consistently, and were contributed by completely untrained volunteers on an opportunistic basis. Photo submissions were uploaded to the website and fields for location and collection date were filled in by the photo contributor. Because the volunteers were untrained, the quality of photographs was overall lower, meaning that a smaller proportion of these photographic sightings could be used for analyses (see photo quality criteria in "*Photo Processing"* section). Only photo entries where the contributor explicitly indicated that the image was collected in the Juneau tour area were considered. Table 1.2 provides a summary of effort by dataset (dedicated survey versus citizen science).

Citizen Science Bias

To measure bias in citizen science data versus the dedicated survey data, we compared estimates of abundance and multiple measures of residency acquired using each dataset and the combined datasets. We report the percent difference in parameter values between citizen science and dedicated survey datasets.

Abundance

Sighting histories, pooled by month, were constructed for all individual humpback whales seen in this study from the truncated dataset (poor quality photos removed), and estimates of abundance were made using a POPAN model in program Mark 8.0, a software package designed to analyze mark-recapture data [35]. We elected to use the POPAN model, as it provides estimates that consider immigration into the study area [36]. The POPAN model is a variation of the Jolly-Seber model and assumes the following [37]:

1. Each whale in the population has the same probability of capture at the time of sampling.
2. Each whale has the same probability of surviving between two sampling occasions.
3. Marks are not lost, and all marks are reported (i.e. flukes are identifiable over time).

4. Sampling is instantaneous, relative to the interval between sampling occasions.

Assumption 1, as it applies to this study, is that there will be no heterogeneity in the likelihood that an individual will be sighted (captured). Less distinguishable individuals cannot be identified when the photo quality is compromised, functionally reducing the probability of being sighted relative to more distinctive individuals. This bias can be mitigated by eliminating poor quality images [31,33], as we have done in this analysis (see "*Photo Processing*" section). Heterogeneity from individual whale behavior or survey bias can still be present, but is harder to control for. Assumption 2 is inherently satisfied, as humpback whales have a high survival rate relative to the sampling intervals, and there is no reason to expect that surveys would alter their survival [33,38,39]. Assumption 3 is satisfied when photo identifications are performed by experienced matchers, as was done in this study [31]. Lastly, strict compliance with Assumption 4 is unrealistic in all studies, particularly with a widespread population such as humpback whales. A violation of this assumption affects survival estimates and has a greater impact on the results in studies with shorter-lived species [40]. Because humpback whales are long-lived [41], the effects of this violation are minimal, and the survey interval proposed (weekly, and data pooled by month) is sufficient.

For our mark-recapture analyses, various combinations of parameters were modeled. POPAN models estimate survival, φ, probability of capture, *p*, the net number of new entrants into the population, *pent*, estimates of abundance, $\widehat{N}$, and an estimate of the super population, $\widehat{N}^*$, a parameter that describes all whales that are part of the population or that could become part of the population through immigration and reproduction. We constructed models with all combinations of: survival estimated constant, $\varphi(.)$, and set to 0.96, $\varphi(0.96)$, per Mizroch *et al*. [38]; *p* estimated constant, *p(.)*, or with time effects, *p(t)*; and *pent* estimated constant, *pent(.)*, or with time effects, *pent(t)*. All models estimated $\widehat{N}$ by month, by year, and over the course of the study (2013 – 2014), and a single $\widehat{N}^*$ estimate. We used the Akaike Information Criterion corrected for small samples sizes (AICc) to select the most parsimonious model as described by Burnham and Anderson [42].

Residency

Population estimates represent the cumulative number of humpback whales that use the tour area at any point during the summer, but not all of these whales stay in the area throughout the season. The occurrence of transients, which do not reside near Juneau but are sighted while transiting through the study area, can lead to over-estimation of resident abundance [43]. The length of time that whales persist in the study area is highly variable among individuals. To better characterize the area use by humpback whales sighted/estimated in this study, we employed several tools to estimate seasonal retention, namely: site fidelity, transience, residency rate, Lagged Identification Rate (LIR) and discovery curves. Because these analyses are sensitive to heterogeneity in sightability from photo quality, the truncated datasets (poor quality photos removed) were used for all five analyses.

1) Site fidelity: Calculated as the cumulative ratio of re-sighted individuals to the total number of individuals sighted by year.

2) Transience: Estimated as the proportion of all individual whales sighted during a year that have only a single sighting within the season.

3) Residency rate: We adopted the same definition for residency as is used in the longitudinal study of humpback whales in GBNP. A whale was considered "resident" for a given season if it is was sighted multiple times over a 20-day period [29]. This does not exclude whales that may have temporarily emigrated from the area, but does attempt to remove whales that only transited through the area. The residency rate is the proportion of the total number of whales identified per season that were classified as residents.

4) LIR: This model summarizes movements out of and into the study area, and generates an estimate for average residency days by individuals in the study. LIR is the probability that an individual sighted will be sighted again in later surveys. This analysis was done using software SOCPROG 2.7 [44], following methods used by [45].

5) Discovery curve: This is the cumulative number of individual whales over the course of the study and is displayed by dataset. A discovery curve is useful to visually depict the rate of discovery of "new" whales to the study area and demonstrate the level of "openness" (immigration and births) inherent in a population.

Results

Effort between years and datasets varied (Table 1.2). The citizen science dataset had relatively few sightings and unique IDs in 2013 compared with the dedicated surveys. However, in 2014, when effort was increased (a results of increased involvement by Gastineau Guiding Company), there were more sightings (~250%) and unique IDs (~19%) than in the dedicated survey.

Abundance

Estimates of humpback whale abundance in the Juneau tour area were made by month and year using each dataset (dedicated survey and citizen science) and the combined dataset (all data). The selected model has an estimated constant survival, φ, time-dependent *p*, and time-dependent *pent* ($\varphi(.)$ $p(t)$ $pent(t)$ $\widehat{N}^*$). This model had the lowest AICc for the dedicated survey data and the citizen science data. For the pooled data (all data), this model ($\varphi(.)$ $p(t)$ $pent(t)$ $\widehat{N}^*$) was ranked second best fit (**Δ** AICc = 4.1; Table 1.4). However, we opted to use this model for all datasets so that we could make direct comparisons to results across all datasets.

The abundance and survival estimates from the different datasets were varied. Citizen science data provided a 33% higher estimate of abundance than the dedicated survey in 2013 when effort was low, and a 4% higher estimate in 2014, when effort was high. For the overall abundance estimate, using data from both years, the estimate made from citizen science data was higher than the dedicated survey result by 13% (Fig. 1.3). Regardless of dataset used, the monthly abundance estimates increased throughout the season (Fig. 1.4). Survival, φ, was estimated constant throughout the study as follows: all data = 0.50, dedicated survey = 0.59, citizen science = 0.30. These values represent “survival” in the study area, where permanent emigration is equivalent to mortality (1-survival) in the model.

Residency

Residency was evaluated using five measures to describe the movements of humpback whales into and out of the Juneau study area. Compared with the dedicated survey, citizen science data resulted in higher estimates of site fidelity (13% in 2013 and 31% in 2014) and residency rate (54% in 2013 and 11% in 2014) and lower estimates of transience (17% in 2013 and 19% in 2014) and LIR (9% for both 2013 and 2014) (Table 1.5). For these residency measures, the relative bias was not reduced with increased effort between the 2013 and 2014 seasons. Discovery curves for the dedicated survey data and the citizen science data arrived at the same cumulative total number of individual whales observed over the course of the study, but when data from both surveys were combined, the total number of unique individuals was considerably higher.

Summary of Suggested Estimates for Humpback Whales in the Juneau Area

Humpback whale abundance estimates for the Juneau area were best estimated using the combined dataset (all data, including both citizen science and dedicated survey data; Table 1.6). Specifically, these estimates were closest to the known minimum abundance (total unique individuals regardless of photo quality), whereas other datasets produced estimates that were lower than the known minimum.

Our suggested estimates of residency are from the dedicated survey dataset because of the additional bias observed in the results using citizen science data. Estimates of site fidelity from the dedicated survey dataset were 45% in 2013 and 51% in 2014. Residency rates were 28% in 2013 and 37% in 2014. Transience was estimated at 58% in 2013 and 52% in 2014. The LIR estimates of mean residency were 50.6 days (20.2 - 154.5) in 2013 and 74.5 days (32.2 - 174.5) in 2014.

Discussion

The purpose of this study was to evaluate bias in humpback whale monitoring data that were collected through a citizen science program, and suggest population parameter estimates for humpback whales in the Juneau area. Citizen science data were compared to data collected from a dedicated survey that operated during the same time and geographic extent.

Data collected through citizen science programs can be useful if the study is properly designed and the methods have been validated [1,17]. This has been demonstrated in other studies; for example, Bruce et al. [9] investigated geospatial patterns in habitat preferences of mother-calf pairs in Australian waters using sightings recorded from whale-watching vessels. The inherent bias from the use of tourism platforms was acknowledged, and addressed by introducing intensive volunteer training and applying various statistical randomization tests. Similarly, data on grey reef shark (*Carcharhinus amblyrhynchos*) presence were collected by citizen scientists (professional scuba dive guides) and were validated using telemetry of tagged sharks. Authors found a strong correlation between datasets and concluded that citizen science should be used to contribute to coral reef shark monitoring efforts [46].

Biases in Citizen Science Data

Sources of bias in survey data can be characterized as having two sources: observer bias and survey bias. All field studies are susceptible to these forms of bias; however, we focus on characterizing bias specific to citizen science surveys in this study. This study uses our own dedicated survey as a reference, but we acknowledge that there is inherent heterogeneity in whale behavior and some degree of observer and survey bias, regardless of the experience level of the observer and structure of the survey design [31,47]. Observer bias is introduced by error on the part of the observer, and could potentially be higher for citizen science data, as the observers are generally less experienced. However, photo-identification data may be particularly robust to observer bias. Untrained participants can capture images that identify individual whales without the photographer needing to make subjective decisions about the identity of the animal. Identifying photographs can then be matched or verified by trained individuals after the fact, thereby reducing potential error in matching from less experienced users. Associated data recorded by novice observers (location, time, date, distinguishing calves from non-calves, associations, behavior, etc.) are more susceptible to observer biases. Still, there are ways to work around these issues by automating certain metadata (e.g., location, time, date) with GPS camera attachments and use of camera date/time stamps, and by limiting analyses to those that do not require experienced observer data (calf data, associations data, behavior, etc.). It is also expected that the overall quality of photographs from novice observers would be lower, but this is controlled for by implementation of a photo quality standard (see *"Photo Processing" section*). For the citizen science data in this study, we used photographs for identification that were verified by an expert matcher and associated date and location data, which were automated, where possible, to reduce the impact of observer bias.

Survey bias is inherent to field methods. All field survey methods have sources of survey bias, but citizen science and platforms of opportunity often have additional constraints that need to be considered. For example, whale-watching boats cannot acquire research permits that would allow them to approach whales within 100 yards for increased photo identification efficiency and quality. Further, the structure and constraints of a tour likely skew whale sightings to whales that are more accessible and more surface-active. Captains are also more likely to return to areas where they previously found whales, rather than searching randomly. In other words, whale-watching platforms are likely to have increased issues with heterogeneity relative to data collected from scientific platforms. In this study, we pooled all sightings by month for our analyses, which works to reduce the effect of heterogeneity. However, we acknowledge that heterogeneity is likely more of an issue in the citizen science data than in dedicated surveys.

We expected that the citizen science dataset would be associated with higher levels of observer bias (novice observers) and survey bias (from tour constraints), relative to the dedicated surveys. However, we expected these biases to be tempered as the number of sightings increased. In other words, increased effort can compensate for potential bias. In 2013, the citizen science effort was relatively low and produced only 70% of the sightings collected by the dedicated survey during the same year. In contrast, 2014 yielded a high volume of data from the citizen science program, with approximately 2.5 times as many sightings as the dedicated survey. This provided the opportunity to evaluate citizen science data at different effort levels. We expected data from 2014 to be more consistent with the data from dedicated surveys than the 2013 data due to the relative effort allocated.

As expected, we found that the citizen science data were biased toward repeat sightings relative to data from dedicated surveys. Whale-watching captains are likely to return to areas where whales were previously spotted rather than surveying the area for new whales, where the chance of whale sighting is less certain. This resulted in higher estimates of site fidelity and residency, and lower estimates of transience compared to the dedicated survey. The magnitude of presumed bias was not inversely related to effort (number of sightings) for these measures. The LIR estimates of mean residency days were lower by only 9% in each year. However, LIR mean residency estimates from all datasets have large confidence intervals relative to the magnitude of the estimate. Therefore, we are not able to make clear conclusions about the differences in LIR by dataset, due to lack of precision. The discovery curves did not asymptote (Fig. 1.5), regardless of the dataset used, indicating either that the majority of individuals in the population have not yet been sighted (i.e., the population is much larger than what has already been documented), or that there is a high degree of immigration. The citizen science data showed a lower number of unique individuals in 2013, when effort was low, but was then comparable with the dedicated survey in 2014, when effort was higher.

Bias in citizen science data was more complicated in its influence on estimates of humpback whale abundance. We expected that estimates would be biased low due to increased favorability for repeated sightings (heterogeneity). Indeed, this was the case for 2013 when effort was low, but not for 2014 or overall 2013 – 2014 estimates. The 2013 citizen science estimates of abundance were especially different (33% lower than the dedicated survey results), whereas the 2014 and overall citizen science estimates were more similar (4% and 13% higher than the dedicated survey results, respectively). Further, we found evidence in our estimates of abundance for the importance of increased effort outweighing the risk from additional bias. The number of unique individuals sighted (using all available data, regardless of collection method or photo quality) is the known minimum abundance; therefore, both the citizen science and dedicated surveys are biased low (see Fig. 1.3, dashed line indicates known minimum number of individuals). This is not surprising, as heterogeneity in humpback whale sightings is a known cause of the underestimation of abundance [25,33,37,48–50]. In fact, the citizen science estimates of abundance for 2014 and overall 2013 – 2014 show more realistic estimates (closer to the known minimum) than estimates from the dedicated survey. This indicates that the larger number of sightings to some extent counteracted the negative bias associated with heterogeneity. Therefore we believe that the increased effort from the combined datasets ("all data") provides the most accurate estimates of whale abundance in the study region during summer.

Given the results of this study, we recommend that, where possible, estimates of abundance for purposes of monitoring humpback whales be made using all available data, including data collected by citizen scientists. We have shown through this study that it is possible to solicit large volumes of humpback whale citizen science data that can effectively be used for estimation of abundance and can therefore be valuable for monitoring. Given the relationship between effort and accuracy in estimates, we suggest considering ways to increase the volume of citizen science data collected (through outreach and solicitation) in these studies as it will likely reduce bias. However, caution should be exercised when interpreting estimates of residency (site fidelity, residency rate, the inverse of transience, LIR) from citizen science datasets. These results may not be comparable to estimates of retention from other studies, but could be useful in longitudinal studies as relative measures over time. However, because estimates are influenced by the amount of effort, the relative effort is constant over time or is adjusted for in the analysis.

Comparison to Other Humpback Whale Population Estimates

Because our study area is smaller than the areas used in other analyses of humpback whales in Alaska, the influence of small-scale movements has a greater impact on population estimates [37]. Specifically, this movement effectively decreased estimates of survival, site fidelity, residency rate, and increased estimates of transience and LIR. Our selected model estimates survival at 0.499 (0.328 - 0.671). Because mortality (1-survival) and emigration are confounded in the model, “survival” indicates a measure of persisting in the study area, not actual survival. Therefore, these estimates cannot be directly compared with true survival estimates from other studies of larger geographic regions. That said, the intention of this study was to estimate abundance and residency, not localized “survival.”

The small size of our study area also affected the measures of residency. Reported estimates of residency rates are higher in GBNP, where the study area is approximately four times larger [29]. Our residency rates were 28% and 37% for 2013 and 2014, respectively. In contrast, for the same years, GBNP had a residency rate of 62% in 2013 and 63% in 2014 [29,51]. Intuitively, the larger the spatial coverage, the more movement within the study area is possible without a whale “emigrating,” in effect, increasing the residency rate. Further, Hendrix et al. [52] reported >75% area fidelity in southeast Alaska humpbacks in 1994 – 2008; considerably higher than our estimates of 45% in 2013 and 51% in 2014. Similarly, Calambokidis et al. [21] reported 65% of humpback whale sightings in the North Pacific Basin were re-sights in the same region, indicating low interchange between areas. In a genetic analysis of mitochondrial DNA, Baker et al. [23] showed a strong maternally directed site fidelity to the feeding grounds in humpback whales throughout the North Pacific Ocean. Using a combination of genetic data and trophic level (determined from stable isotopes), Witteveen et al. [24] demonstrated lasting distinctiveness in the inshore and offshore waters of southeast Alaska (along with other regions throughout Alaska). This indicates that whales are consistently feeding in the same regions and that genetic exchange between southeast Alaska and other regions in Alaska is rare.

Despite the smaller study area with more movement into and out of the geographical limits relative to the total abundance, we believe that it is critical to evaluate the humpback whale population parameters specific to the Juneau area. This is the only way that managers would effectively be able to evaluate changes in attendance and movement of whales potentially caused by vessel disturbance or other anthropogenic or natural causes. This is especially important in the face of rapid increase in the number of tour vessels in this area that could be directly impacting the whales that use this area. That said, the estimates presented in this study should be interpreted with consideration of the smaller spatial scale, and comparisons of survival and residency to larger geographic regions should be done cautiously, if at all.

Conclusions

This study provides an objective assessment of humpback whale photo identification data collected through a citizen science program. Our results verify that the citizen science data were biased compared with data collected from a dedicated platform by experienced observers. However, the magnitude of this bias is inversely related to effort for estimates of abundance. We show that with enough effort, citizen science data can be as (or more) accurate than dedicated survey data in estimates of humpback whale abundance. Bias in the citizen science data was more pervasive for estimates of residency, and we recommend that these measures be used only as a relative measure (e.g., comparing citizen science data across years where similar effort was made to detect relative changes in residency). We believe that citizen science data can be valuable for monitoring humpback whales, and we recommend that data be collected where willing participants are available. As for all studies, it is important to acknowledge potential bias and interpret data with knowledge of the ways that this bias may be affecting results. While there is greater potential for bias in citizen science data, we show here that there are still useful measures that can be attained from these data.

Exploring practical methods for humpback whale monitoring data collection is especially relevant, given limited funding for marine mammal research. Lack of consistent finding makes long-term monitoring studies difficult or impossible. However, longitudinal datasets are critically important for populations in flux or populations facing anthropogenic threats, such as humpback whales. Strategies for monitoring humpback whales in Alaska are especially relevant given humpback whales were recently reclassified under the ESA, and the Hawaii DPS (that makes up 95% of southeast Alaska's summertime population) are no longer listed under the ESA [26]. However, there are no funds specifically dedicated for post-delisting monitoring. Further, the reclassification of some humpback whale DPSs may actually make it more difficult to procure funding, as many funding agencies prioritize research of ESA listed species. Therefore, it may be more important than ever to employ creative and cost effective methods, such as citizen science, to collect monitoring data for humpback whales. In many areas, citizen science programs may be the only feasible option for collecting these data.

Lastly, we re-emphasize that citizen science provides a unique opportunity to educate and engage the public in the scientific process. We believe that empowering the whale-watching industry to contribute to science increases their scientific literacy and environmental stewardship standards by exposing them to field methods used for monitoring, and ultimately, conservation of the species. The added outreach and conservation benefit of citizen science programs should be acknowledged when programs are being considered.

Acknowledgements

This project was funded by the National Science Foundation Marine Ecosystem Sustainability in the Arctic and Subarctic IGERT (Award #DGE-0801720) and the North Pacific Research Board (G8728). Thank-you to Gastineau Guiding Co for their extensive participation in this project, in particular, B. Janes, S. Ranger, and B. Hauser. Also, we appreciate the support of Juneau Flukes research non-profit, and the participants who contributed photographs and data through the www.JuneauFlukes.org website. We gratefully acknowledge the University of Alaska Southeast and Glacier Bay National Park for their collaboration and for use of the Southeast Alaska humpback whale catalog and numbering system. Special thanks to M. Peterson, K. Anderson, L. Short-Forrer, and the many others, who assisted as field volunteers, and to F. Mueter and J. Laake for assistance with the analyses. Thank-you to B. Witteveen, F. Mueter, A. Beaudreau, and D. DeMaster for their contributions to the study design and editorial comments on the manuscript.

References Cited

1. Irwin A. Citizen science: A study of people, expertise, and sustainable development. New York: Routledge; 1995.
2. Aïssi M, Arcangeli A, Crosti R, Daly Yahia MN, Loussaief B, Moulins A, et al. Cetacean occurrence and spatial distribution in the central Mediterranean Sea using ferries as platform of observation. Russ J Mar Biol. 2015;41: 343–350. doi:10.1134/S1063074015050028
3. Kiszka J, Macleod K, Van Canneyt O, Walker D, Ridoux V. Distribution, encounter rates, and habitat characteristics of toothed cetaceans in the Bay of Biscay and adjacent waters from platform-of-opportunity data. ICES J Mar Sci. 2007;64: 1033–1043. doi:10.1093/icesjms/fsm067
4. Duffy LM. Patterns of habitat use by harbor porpoise. San Francisco State University. Thesis. 2015.
5. Williams R, Hedley SL, Hammond PS. Modeling distribution and abundance of Antarctic baleen whales using ships of opportunity. Ecol Soc. 2006;11. Available: http://www.ecologyandsociety.org/vol11/iss1/art1/
6. Higby LK, Stafford R, Bertulli CG. An evaluation of ad hoc presence-only data in explaining patterns of distribution: Cetacean sightings from whale-watching vessels. Int J Zool. 2012;2012: 1–5. doi:10.1155/2012/428752
7. Kilponen A. The Use of whale watching data on cetacean research: cetaceans in the Northern Pelagos Sanctuary, Italy. Stockholm University. 2015.

8. Hupman K, Visser I, Martinez E, Stockin K. Using platforms of opportunity to determine the occurrence and group characteristics of orca (*Orcinus orca*) in the Hauraki Gulf, New Zealand. New Zeal J Mar Freshw Res. 2014;49: 132–149. doi:10.1080/00288330.2014.980278

9. Bruce E, Albright L, Sheehan S, Blewitt M. Distribution patterns of migrating humpback whales (*Megaptera novaeangliae*) in Jervis Bay, Australia: A spatial analysis using geographical citizen science data. Appl Geogr. 2014;54: 83–95. doi:10.1016/j.apgeog.2014.06.014

10. Ryan CG, Whooley P, Berrow SD, Barnes C, Massett N, Strietman WJ, et al. A longitudinal study of humpback whales in Irish waters. J Mar Biol. 2015;96: 1–7. doi:10.1017/S0025315414002033

11. Moura AE, Sillero N, Rodrigues A. Common dolphin (*Delphinus delphis*) habitat preferences using data from two platforms of opportunity. Acta Oecologica. 2012;38: 24–32. doi:10.1016/j.actao.2011.08.006

12. Tonachella N, Nastasi A, Kaufman G, Maldini D, Rankin RWM. Predicting trends in humpback whale (*Megaptera novaeangliae*) abundance using citizen science. Pacific Conserv Biol. 2012;18: 297–309.

13. Clapham PJ, Baraff LS, Carlson CA, Christian MA, Mattila DK, Mayo CA, et al. Seasonal occurrence and annual return of humpback whales, *Megaptera novaeangliae*, in the southern Gulf of Maine. Can J Zool. 1993;71: 440–443. doi:10.1139/z93-063

14. Rosenbaum HC, Weinrich MT, Stoleson S a, Gibbs JP, Baker CS, Desalle R. The effect of differential reproductive success on population genetic structure: correlations of life history with matrillines in humpback whales of the Gulf of Maine. Am Genet Assoc. 2002;93: 389–399.

15. Embling CB, Walters AEM, Dolman SJ. How much effort is enough? The power of citizen science to monitor trends in coastal cetacean species. Glob Ecol Conserv. 2015;3: 867–877. doi:10.1016/j.gecco.2015.04.003

16. Tyne JA, Loneragan NR, Johnston DW, Pollock KH, Williams R, Bejder L. Evaluating monitoring methods for cetaceans. Biol Conserv. Elsevier Ltd; 2016;201: 252–260. doi:10.1016/j.biocon.2016.07.024

17. Hart A, Stafford R, Goodenough A, Morgan S. The role of citizen science and volunteer data collection in zoological research. Int J Zool. 2012; doi:10.1155/2012/105345

18. Follett R, Strezov V. An analysis of citizen science based research: Usage and publication patterns. PLOS ONE. 2015;10: 1–14. doi:10.1371/journal.pone.0143687

19. New LF, Hall AJ, Harcourt R, Kaufman G, Parsons ECM, Pearson HC, et al. The modeling and assessment of whale-watching impacts. Ocean Coast Manag. 2015;115: 10–16. doi:10.1016/j.ocecoaman.2015.04.006

20. Alaska Department of Commerce, Community and Economic Development. Alaska Visitor Statistics Program VI. 2012.

21. Calambokidis J, Steiger GH, Straley JM, Herman LM, Cerchio S, Salden DR, et al. Movements and population structure of humpback whales in the North Pacific. Mar Mammal Sci. 2006;17: 769–794. Available: http://onlinelibrary.wiley.com/doi/10.1111/j.1748-7692.2001.tb01298.x/abstract

22. Straley JM, Gabriele CM, Baker SC. Seasonal characteristics of humpback whales (*Megaptera novaeangliae*) in southeast Alaska. Proc Third Glacier Bay Sci Symp. 1993; 229–238.

23. Baker C, Steel D, Calambokidis J, Falcone E, González-Peral U, Barlow J, et al. Strong maternal fidelity and natal philopatry shape genetic structure in North Pacific humpback whales. Mar Ecol Prog Ser. 2013;494: 291–306. doi:10.3354/meps10508

24. Witteveen B, Straley J, Chenoweth E, Baker C, Barlow J, Matkin C, et al. Using movements, genetics and trophic ecology to differentiate inshore from offshore aggregations of humpback whales in the Gulf of Alaska. Endanger Species Res. 2011;14: 217–225. doi:10.3354/esr00351

25. Calambokidis J, Falcone EA, Quinn TJ, Burdin AM, Phillip J, Ford JKB, et al. SPLASH : Structure of populations, levels of abundance and status of humpback whales in the North Pacific. Final report for Contract AB133F-03-RP-00078, US Dept of Commerce Western Admin. Center, Seattle, WA. Seattle, WA; 2008.

26. NOAA. Endangered and Threatened Species; Identification of 14 Distinct population segments of the humpback whale (*Megaptera novaeangliae*) and revision of species-wide listing. 50 CFR Parts 223 and 224 2016 pp. 62260–62320.

27. Wade PR, Quinn TJ, Barlow J, Baker CS, Burdin AM, Calambokidis J, et al. Estimates of abundance and migratory destination for North Pacific humpback whales in both summer feeding areas and winter mating and calving areas. Submitted to Sci Comm Int Whal Comm June 2016, Bled, Slovenia.

28. NOAA. Post-delisting monitoring plan for nine distinct population segments of the humpback whale (*Megaptera novaeangliae*) NOAA/NMFS DRAFT. 2016.

29. Neilson J, Gabriele CM, Vanselow PBS. Humpback whale monitoring in Glacier Bay and adjacent waters 2014 Annual Progress Report. Gustavus, Alaska; 2015.

30. Katona SK, Whitehead HP. Identifying humpback whales using their natural markings. Polar Rec (Gr Brit). 1981;20: 439–444. Available: http://journals.cambridge.org/abstract_S003224740000365X

31. Friday N, Smith T. Measurement of photographic quality and individual distinctiveness for the photographic identification of humpback whales, *Megaptera novaeangliae*. Mar Mammal Sci. 2000;16: 355–374. Available: http://onlinelibrary.wiley.com/doi/10.1111/j.1748-7692.2000.tb00930.x/abstract

32. Katona S, Baxter B, Brazier O, Kraus SD, Perkins J, Whitehead H. Identification of humpback whales by fluke photographs. In: Winn HE, Olla BL, editors. Behavior of Marine Animals. New York; 1979. pp. 33–44. doi:10.1007/978-1-4684-2985-5

33. Teerlink SF, von Ziegesar O, Straley JM, Quinn TJ, Matkin CO, Saulitis EL. First time series of estimated humpback whale (*Megaptera novaeangliae*) abundance in Prince William Sound. Environ Ecol Stat. 2015;22: 345–368. doi:10.1007/s10651-014-0301-8

34. NOAA. Regulations governing the approach to humpback whales in Alaska. 2004.

35. Cooch E, White G. Program MARK; a gentle introduction [Internet]. 2009. p. 819. Available: http://warnercnr.colostate.edu/~gwhite/mark/mark.htm

36. Schwarz CJ, Arnason AN. A general methodology for the analysis of capture-recapture experiments in open populations. Biometrics. 1996;52: 860–873. Available: http://www.jstor.org/stable/10.2307/2533048

37. Seber G. The estimation of animal abundance. 2nd ed. New York: Wiley; 1982.

38. Mizroch S, Herman L, Straley JM, Glockner-Ferrari D, Jurasz CM, Darling J, et al. Estimating the adult survival rate of central North Pacific humpback whales (*Megaptera novaeangliae*). J Mammal. 2004;85: 963–972. Available: http://asmjournals.org/doi/pdf/10.1644/BOS-123

39. Zerbini AN, Clapham PJ, Wade PR. Assessing plausible rates of population growth in humpback whales from life-history data. Mar Biol. 2010;157: 1225–1236. doi:10.1007/s00227-010-1403-y

40. Lindberg M, Rexstad E. Capture–recapture sampling designs in: Encyclopedia of Environmetrics. El-Shaarawi AH, Piegorsch WW, editors. Chichester: John Wiley and Sons; 2002.

41. Gabriele CM, Lockyer C, Straley JM, Jurasz CM, Kato H. Sighting history of a naturally marked humpback whale (*Megaptera novaeangliae*) suggests ear plug growth layer groups are deposited annually. Mar Mammal Sci. 2010;26: 443–450. doi:10.1111/j.1748-7692.2009.00341.x

42. Burnham KP, Anderson DR. Model selection and multimodel inference: A practical information-theoretic approach. 2nd ed. Berlin: Springer; 2003.

43. Madon B, Garrigue C, Pradel R, Gimenez O. Transience in the humpback whale population of New Caledonia and implications for abundance estimation. Mar Mammal Sci. 2012;29: 669–678. doi:10.1111/j.1748-7692.2012.00610.x

44. Whitehead H. SOCPROG programs: analyzing animal social structures. Behav Ecol Sociobiol. 2009;63: 765–778. Available: http://myweb.dal.ca/hwhitehe/Manual.pdf

45. Zanardo N, Parra GJ, Möller LM. Site fidelity, residency, and abundance of bottlenose dolphins (*Tursiops sp.*) in Adelaide's coastal waters, South Australia. Mar Mammal Sci. 2016; 1–21. doi:10.1111/mms.12335

46. Vianna GMS, Meekan MG, Bornovski TH, Meeuwig JJ. Acoustic telemetry validates a citizen science approach for monitoring sharks on coral reefs. PLOS ONE. 2014;9: 1–12. doi:10.1371/journal.pone.0095565

47. Stevick PT, Palsbøll PJ, Smith TD, Bravington M V, Hammond PS. Errors in identification using natural markings: rates, sources, and effects on capture recapture estimates of abundance. Can J Fish Aquat Sci. 2001;58: 1861–1870. doi:10.1139/cjfas-58-9-1861

48. Straley JM, Quinn II TJ, Gabriele CM. Assessment of mark-recapture models to estimate the abundance of a humpback whale feeding aggregation in Southeast Alaska. J Biogeogr. 2008;36: 427–438. doi:10.1111/j.1365-2699.2008.01906.x

49. Calambokidis J, Steiger GH, Straley JM, Quinn TJ, Herman LM, Cerchio S, et al. Abundance and population structure of humpback whales in the North Pacific basin [Internet]. 1997. Available: http://cascadiaresearch.org/Reports/rep-NPAC.pdf

50. Barlow J, Calambokidis J, Falcone E a., Baker CS, Burdin AM, Clapham PJ, et al. Humpback whale abundance in the North Pacific estimated by photographic capture-recapture with bias correction from simulation studies. Mar Mammal Sci. 2011;27: 793–818. doi:10.1111/j.1748-7692.2010.00444.x
51. Neilson JL, Gabriele CM, Vanselow PBS. Humpback whale monitoring in Glacier Bay and adjacent waters 2013 Annual Progress Report. 2014.
52. Hendrix AN, Straley J, Gabriele CM, Gende SM. Bayesian estimation of humpback whale (*Megaptera novaeangliae*) population abundance and movement patterns in southeastern Alaska. Can J Fish Aquat Sci. 2012;69: 1783–1797. doi:10.1139/F2012-101

Figures

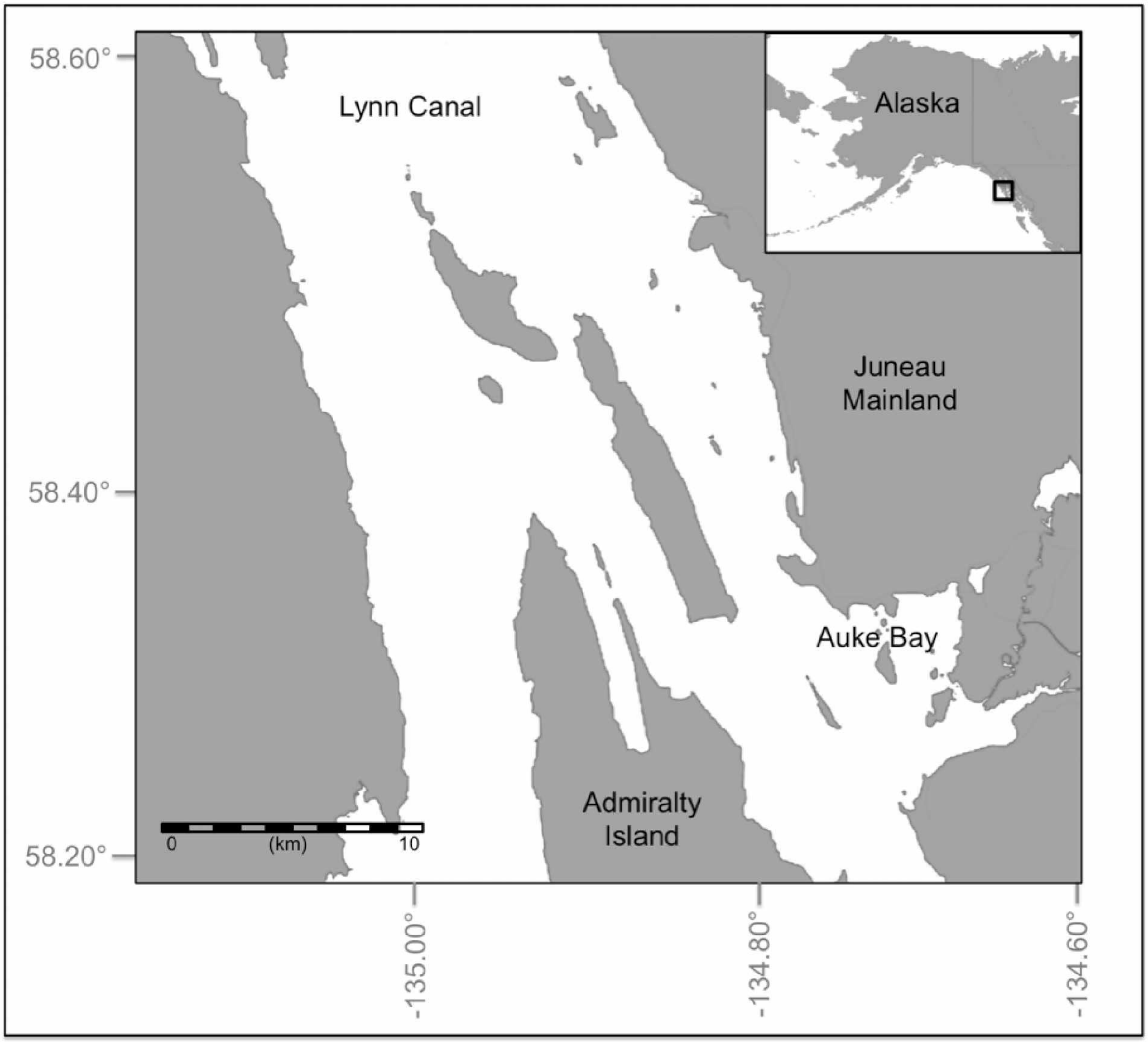

Figure 1.1: Juneau, Alaska tour area and focus of this study. Nearly all of Juneau's whale-watching tourism takes place in this area. Most tours depart from and return to Auke Bay.

Figure 1.2: Humpback whales are individually identifiable by their ventral flukes. This is an example of photo re-identification for SEAK ID 1434 taken over two consecutive years. NMFS Scientific Research Permit # 14296.

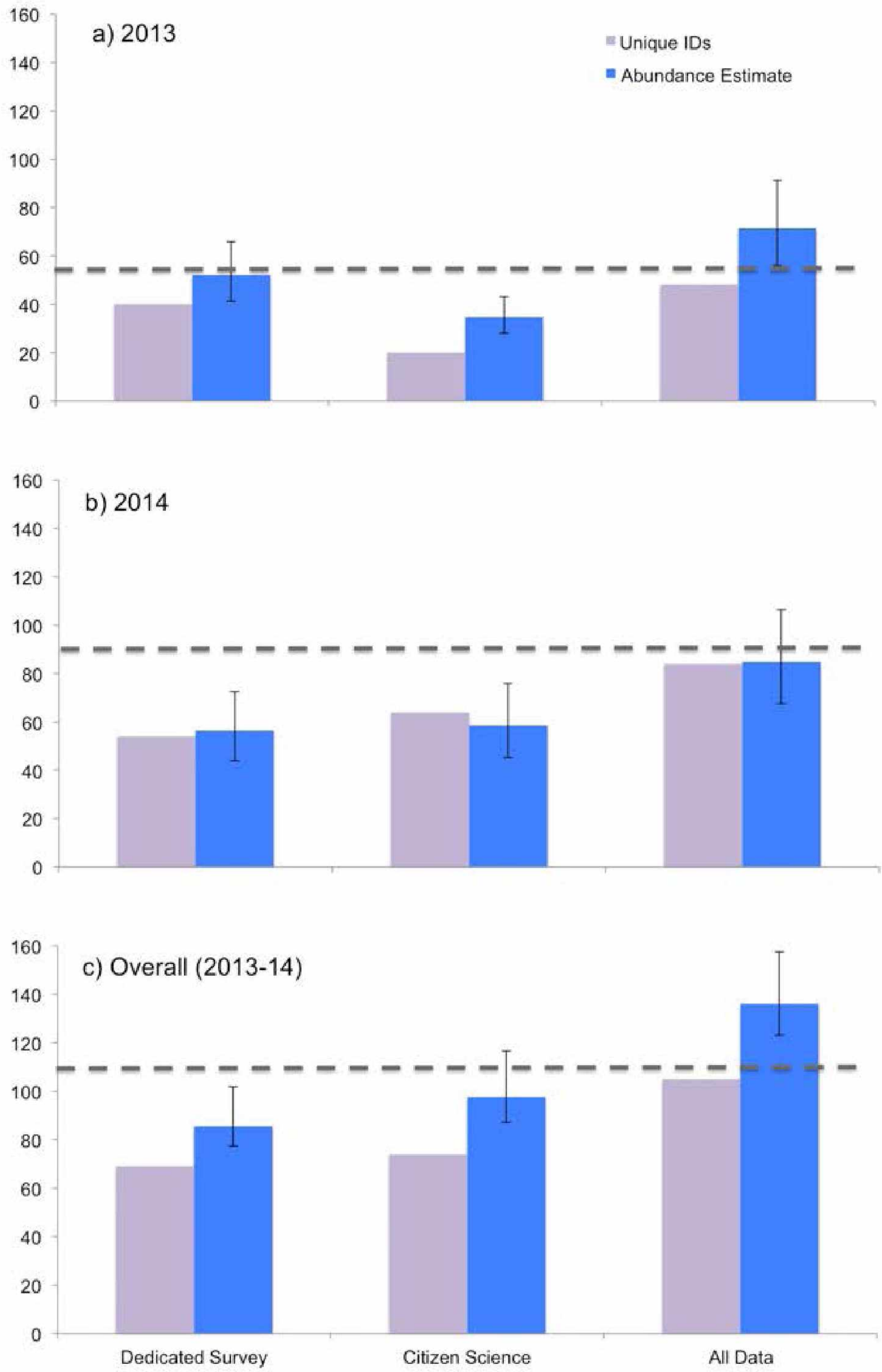

Figure 1.3: Humpback whale abundance estimates by year and the overall estimate for 2013 – 2014 by data source (survey, citizen science, combined). Error bars represent 95% confidence intervals. The number of unique identifications is shown for each year

and for both years combined by data source to indicate the number of individuals included for subsequent analysis. The gray dashed line is the number of unique IDs considering all photos collected (regardless of photo quality). This can be considered a "known" minimum abundance estimate and can be useful to ground-truth estimates (2013 = 54, 2014 = 89, and 2013 – 2014 = 112).

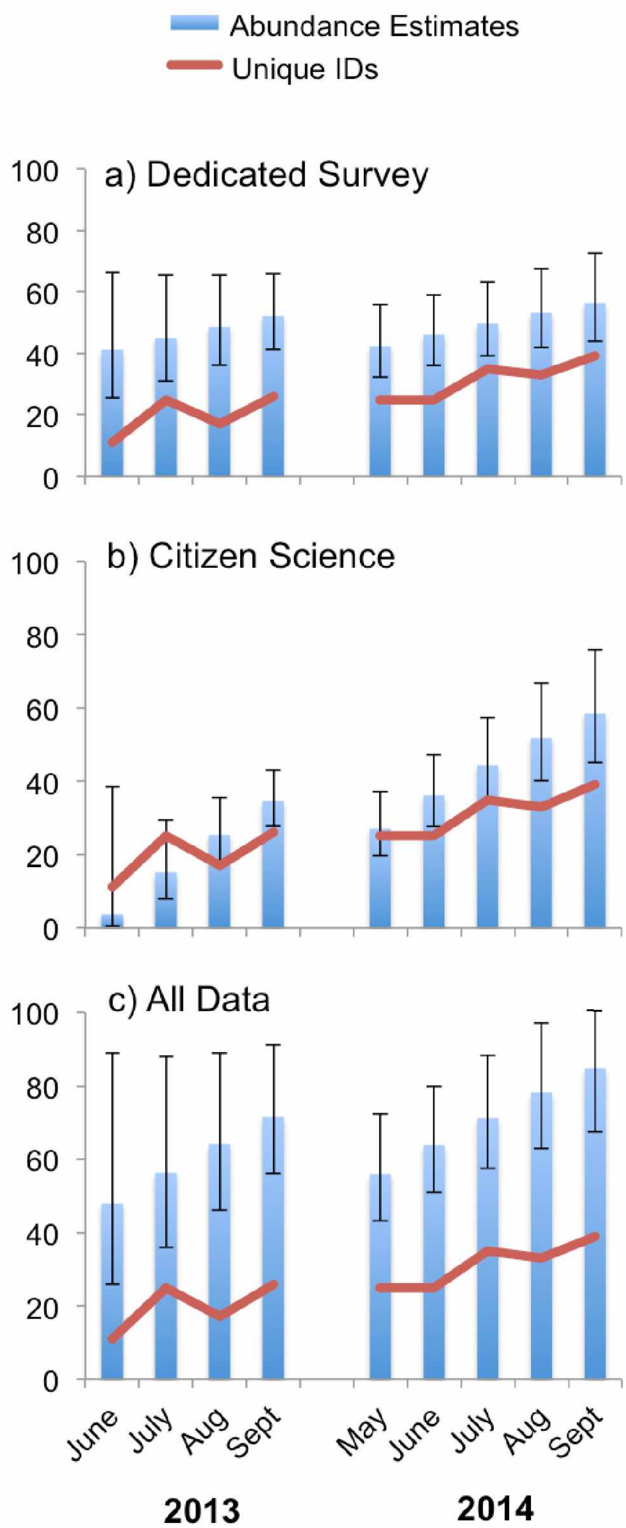

Figure 1.4: Monthly abundance estimates for humpback whales in the Juneau area by data source (survey and citizen science) and combined data. Error bars represent 95%

confidence intervals. The red line (Unique IDs) indicates the number of individuals sighted in that time period, regardless of data source or photo quality. This can be considered a “known” minimum abundance estimate and can be useful to ground truth-estimates (2013: June = 11; July = 25; August = 17; September = 26; and for 2014: May = 25; June = 25; July = 35; August = 33; September = 39).

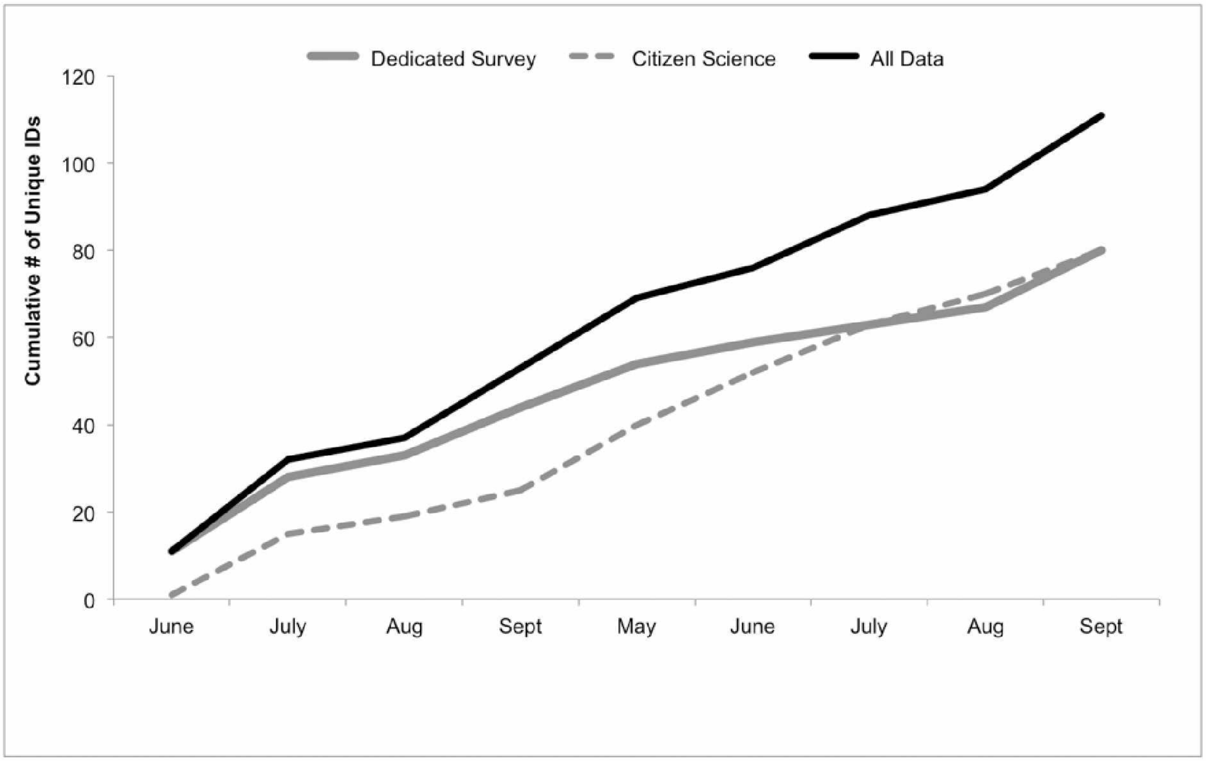

Figure 1.5: Discovery curve showing the cumulative number of individual humpback whales sighted in the Juneau area over the course of the study (2013 – 2014 summers), by dataset (survey, citizen science) and combined.

Tables

Table 1.1: List of dates of dedicated surveys in this analysis. There were no surveys in May for 2013.

2013	**2014**
6/19/13	5/17/14
6/23/13	5/30/14
6/28/13	6/6/14
7/4/13	6/17/14
7/16/13	6/28/14
7/22/13	7/4/14
7/27/13	7/18/14
8/7/13	7/25/14
8/12/13	8/1/14
8/17/13	7/13/14
9/5/13	8/21/14
9/13/13	8/23/14
8/26/13	8/30/14
9/24/13	9/10/14
	9/12/14
	9/13/14
	10/7/14
	9/29/14

Table 1.2: Summary of effort in the humpback whale dedicated survey and citizen science platform of opportunity in the Juneau area, 2013 – 2014. Survey days include the number of calendar days where effort and/or sightings were reported, intended to depict relative number of days with effort (there was a total of 147 available days in the 2013 and 2014 tour seasons). If multiple whale-watching trips reported sightings in a single day, this was still only recounted as one day. In addition, all hours during whale-watching tours are reported as "on effort", even though there are often constraints on how much effort can be dedicated to data collection during a citizen science tour. Effort data were not available for sightings contributed through the website.

	Surveys Days		**Hours on Effort**	
Year	2013	2014	2013	2014
Dedicated Survey	14	23	60	79
Citizen Science	19	96	51	423

Table 1.3: Summary of all humpback whale sighting data used in this study shown by data source: dedicated surveys, all citizen science data, each citizen science source (whale-watching and website) and all data (both dedicated survey and citizen science datasets pooled) collected in the Juneau area in 2013 and 2014. 'Total Sightings' indicates the total number of photo-identifications recorded and 'Unique IDs' are the total number of unique humpback whales cataloged during that year.

	All Photos				**Poor Quality Photos Removed**			
	Total Sightings		**Unique IDs**		**Total Sightings**		**Unique IDs**	
Year	2013	2014	2013	2014	2013	2014	2013	2014
Dedicated Survey	100	164	44	57	85	144	40	54
Citizen Science Total	70	420	26	67	57	347	20	64
Citizen Science: Whale-Watching	45	348	17	55	40	290	14	53
Citizen Science: Website	25	72	17	35	17	57	15	32
All Data	170	584	54	89	142	491	48	84

Table 1.4: Humpback whale mark-recapture model summaries for all parameter combinations modeled by data source. Data are from the Juneau area in 2013 – 2014. Akaike Information Criterion corrected for small samples sizes (AICc) and change in AICc (**Δ** AICc) are shown along with the number of parameters estimated in each model (# Parms). Model parameters are as follows: survival (φ), probability of capture (p), probability of entrance into the population *(pent), and super population* ($\widehat{N}^*$). Parameters were set (value indicated in model name), estimated constant (.), or estimated individually by time (t).

Dedicated Survey

Model	AICc	**Δ** AICc	# Parms
$\varphi(.)\ p(t)\ pent(t)\ \widehat{N}^*$	369.2	---	14
$\varphi(.)\ p(t)\ pent(.)\ \widehat{N}^*$	381.2	12.0	12
$\varphi(0.96)\ p(t)\ pent(t)\ \widehat{N}^*$	382.2	13.0	13
$\varphi(.)\ p(.)\ pent(.)\ \widehat{N}^*$	388.2	19.0	4
$\varphi(0.96)\ p(t)\ pent(.)\ \widehat{N}^*$	389.9	20.7	11
$\varphi(0.96)\ p(.)\ pent(.)\ \widehat{N}^*$	395.9	26.7	3

Citizen Science

Model	AICc	**Δ** AICc	# Parms
$\varphi(.)\ p(t)\ pent(t)\ \widehat{N}^*$	344.1	---	17
$\varphi(.)\ p(t)\ pent(.)\widehat{N}^*$	345.1	1.0	12

Table 1.4 (continued)

φ(.) p(.) pent(.) $\hat{N}^*$	348.0	3.9	4
φ(0.96) p(t) pent(t) $\hat{N}^*$	361.1	17.0	13
φ(0.96) p(t) pent(.) $\hat{N}^*$	368.7	24.6	11
φ(0.96) p(.) pent(.) $\hat{N}^*$	369.1	25.0	3

All Data

Model	AICc	**Δ** AICc	# Parms
φ(.) p(.) pent(.) $\hat{N}^*$	528.5	---	4
φ(.) p(t) pent(t) $\hat{N}^*$	532.6	4.1	16
φ(.) p(t) pent(.) $\hat{N}^*$	537.6	9.1	12
φ(0.96) p(.) pent(.) $\hat{N}^*$	543.9	15.4	3
φ(0.96) p(t) pent(t) $\hat{N}^*$	547.0	18.5	12
φ(0.96) p(t) pent(.) $\hat{N}^*$	557.0	28.5	11

Table 1.5: Residency measures of individual humpback whale retention in the Juneau study area during 2013 and 2014 by data source (dedicated survey, citizen science, combined data). Parameters include site fidelity, transience, residency rate proportions (each shown as percentages), and Lagged Identification Rate (LIR), an estimate of the mean residency in days. The 95% confidence interval for each estimate is shown in parentheses.

	Site Fidelity (%)		**Residency Rate (%)**		**Transience (%)**		**LIR : Mean Residency (Days)**	
Year	2013	2014	2013	2014	2013	2014	2013	2014
Dedicated Survey	45	51	28	37	58	52	50.6 (20.2 - 154.5)	74.5 (32.2 - 174.5)
Citizen Science	51	67	43	41	48	42	46.2 (27.3 - 127.6)	67.7 (35.7 - 122.0)
% Different	**+13%**	**+31%**	**+54%**	**+11%**	**-17%**	**-19%**	**-9%**	**-9%**
All Data	55	68	35	31	59	54	41.9 (21.6 - 74.6)	64.7 (32.5 - 126.6)

Table 1.6: Juneau-area humpback whale parameter estimates from the POPAN mark-recapture model. Estimates include: φ, estimate of survival, *pent*, probability of entrance into the population, $\widehat{N}_{2013-2014}$, overall estimate of abundance over both survey years, $\widehat{N}^*$, estimate of the super population (total number of whales that are in the study area or could move into the study area), $\widehat{N}_{month}$, estimate of abundance by month, and *p*, probability of capture.

	Estimate	95% CI
φ (constant)	0.5	0.3 - 0.7
pent (constant)	0.09	0.06 - 0.1
$\widehat{N}_{2013-2014}$	135.9	123.0 - 157.7
$\widehat{N}^*$ (super population) - derived estimate	140.9	123.8 - 160.5

	$\widehat{N}_{month}$ (Derived Estimate)	95% CI	*p*	95% CI
June 2013	48.0	26.0 - 89.0	0.3	0.1 - 0.5
July 2013	56.3	36.0 - 88.1	0.4	0.2 - 0.6
August 2013	64.1	46.2 - 89.1	0.2	0.1 - 0.4
*September 2013	71.5	56.0 - 91.3	0.3	0.2 - 0.4
May 2014	56.0	43.2 - 72.5	0.4	0.2 - 0.5
June 2014	63.8	51.0 - 79.8	0.4	0.2 - 0.5

Table 1.6 (continued)

July 2014	71.2	57.5 - 88.2	0.5	0.3 - 0.6
August 2014	78.2	62.9 - 97.2	0.4	0.3 - 0.6
*September 2014	84.8	67.6 - 106.5	0.5	0.3 - 0.6

*September estimates of abundance are the end-of-season estimates – these estimates are used to describe the overall annual estimate of humpback whale abundance for that year.

Chapter 2: Blubber and skin steroid hormone concentration to evaluate chronic stress response from whale-watching vessels in humpback whales near Juneau, Alaska[1]

Abstract

A booming whale-watching industry in Juneau, Alaska, is raising concerns over potential impacts on humpback whales (*Megaptera novaeangliae*) and the sustainability of this growing industry. In this study, we investigate the physiological response of these whales to chronic vessel disturbance by measuring hormone concentrations (cortisol, progesterone, testosterone, and estradiol) that have been sequestered in blubber and skin throughout the whale-watch season. We focused our analysis on cortisol, a steroid hormone associated with stress response, and hypothesized that cortisol in biopsy samples will be positively correlated with the amount of vessel traffic in the 3-4 months prior to sampling. Whales in the Juneau area were compared with whales from control areas with far less vessel traffic in both Southeast Alaska and the western Gulf of Alaska using biopsies collected late in the tour season. We did not find elevated cortisol in whales sampled in the Juneau area relative to the Southeast Alaska control area (P=0.14) or sites in western Gulf of Alaska, which had higher cortisol levels (P<0.001). This indicates that high vessel traffic did not result in chronic cortisol sequestration in whales; suggesting whales near Juneau may be habituated to vessel traffic.

---

[1] Teerlink, S., L. Horstmann, and B. Witteveen. Blubber and skin steroid hormone concentration to evaluate chronic stress response from whale-watching vessels in humpback whales near Juneau, Alaska. Submitted to *Endangered Species Research* (*In Review*).

Introduction

Vessel disturbance, both from the physical presence of boats and the associated vessel noise, has been shown to have at least short-term behavioral and physiological impacts on marine mammals (Bejder and Samuels 2003; New et al. 2015). Many studies have documented behavioral changes as a result of vessel disturbance, including: reduced foraging and resting, increased respiration and travel, reduced vocalizations, and vessel evasion (Bejder and Samuels 2003; Quakenbush et al. 2010; Campana et al. 2015; Meissner et al. 2015; Senigaglia et al. 2015; Blair et al. 2016; Cosentino 2016; Culloch et al. 2016; Dunlop 2016; Pérez-Jorge et al. 2016). Moreover, elevated underwater noise (such as noise from excessive vessel traffic) can result in increased cortisol in fishes and marine mammals (Spreng 2000; Wright et al. 2007; Rolland et al. 2012; Nichols et al. 2015).

Whale-watching tourism is a growing industry worldwide, and the increased vessel disturbance from this may be negatively impacting whales (Bejder and Samuels 2003). Several studies have highlighted short-term behavioral responses specific to vessel disturbance from whale-watching tourism. Examples of short-term behavioral responses to vessel disturbance include: increased respiration, movement (vessel evasion), and surface activity, reduced resting and foraging, etc. These type of responses have been documented in humpback whales (*Megaptera novaeangliae*; Corkeron 1995; Stamation et al. 2010; Avila et al. 2015), killer whales (*Orcinus orca*; Trites and Bain 2000; Jelinski et al. 2002), minke whales (*Balaenoptera acutorostrata*;

Christiansen et al. 2013), sperm whales (*Physeter macrocephalus*; Cosentino 2016), and right whales (*Eubalaena glacialis*; Argüelles et al. 2016). Yet, how these short-term behavioral responses by cetaceans translate into long-term impacts remains poorly understood. However, it is important to consider long-term impacts to better understand if these disturbances are persisting and potentially threatening the survival and/or fitness of affected individuals through repeated exposure (Bejder and Samuels 2003; Wright et al. 2009; Hunt and Moore 2013; Scarpaci and Parsons 2014; Atkinson et al. 2015; King et al. 2015; New et al. 2015; Senigaglia et al. 2015).

Long-term stress response is correlated with physiologic markers, such as the concentration of cortisol in certain tissues. Cortisol is a glucocorticoid steroid hormone that is produced when the hypothalamic-pituitary-adrenal axis is activated by stimuli that are perceived to be threatening (Sapolsky et al. 2000; Wingfield and Romero 2011). Like all steroid hormones, cortisol is lipophilic and sequesters in the lipid-rich blubber of cetaceans (Deslypere et al. 1985; Hunt et al. 2013). Blubber, once thought to be only a reservoir for storing energy, is now believed to be a complex metabolic and endocrine organ, which is responsible, in part, for regulating production of hormones and glucose (Kershaw and Flier 2004; Musi and Guardado-Mendoza 2014). For example, relative blubber cortisol concentrations in beluga whales (*Delphinapterus leucas*) were measured in groups entrapped in ice flows *versus* non-entrapped individuals harvested for subsistence use. Blubber cortisol concentrations for entrapped whales were approximately seven times higher than in non-entrapped whales (Trana et al. 2015a). Kellar et al. (2015) investigated short-beaked common dolphins (*Delphinus delphis*) incidentally killed as bycatch in a gillnet fishery (presumably a relatively quick death) and compared them with stranded animals that have a greater likelihood of prolonged stress prior to their death. These authors found that stranded animals had mean blubber cortisol concentrations that were over six times higher than animals killed as bycatch (Kellar et al. 2015). Both studies support the notion that cortisol in blubber is a useful measure of relative stress response in cetaceans.

The process of extracting and measuring steroid hormones in tissues and excretions of free-ranging cetaceans is useful in assessing long-term, averaged hormone levels and has been validated in many other studies. Examples include the use of blubber (Mansour et al. 2002; Kellar et al. 2006, 2013, 2015; Pérez et al. 2011; Noren and Mocklin 2012; Trego et al. 2013; Trana et al. 2015a; b; Vu et al. 2015), lung mucus from blow samples (Hogg et al. 2009; Dunstan et al. 2012; Hunt et al. 2013), and feces (Wasser et al. 2000; Rolland et al. 2005; Hunt et al. 2006; Burgess et al. 2013). Kellar et al. (2013) evaluated progesterone concentrations (also a steroid hormone) in urine, serum, and blubber of bowhead whales (*Balaena mysticetes*) and provided evidence that steroid hormone levels are mirrored among these media. Further, these authors noted that urine and serum steroid hormone concentrations fluctuate on hourly to daily scales while blubber steroid hormone concentrations reflect fluctuations occurring on the scale of weeks to months. In another study, cortisol concentrations in harbor seal (*Phoca vitulina*) blubber and serum were compared and similar conclusions were made on the longer (multi-month) retention of cortisol in blubber (Kershaw and Hall 2016).

Foraging humpback whales near Juneau, Alaska are the focus of a thriving seasonal tourism industry that operates from May — September. Approximately one-quarter of Juneau's summer visitors, over 250,000 travelers, purchase trips on whale-watching excursions (Alaska Department of Commerce, Community, and Economic Development 2012). Ticket sales alone from Juneau whale-watching tours generate more than 30 million U.S. dollars of annual revenue (based on a conservative estimate of $120 average ticket price). Because this ecotourism industry focuses on humpback whales and is the largest (Alaska Department of Commerce, Community, and Economic Development 2012) and most lucrative whale-watching industry in the State of Alaska, Juneau area humpback whales are among Alaska's most economically important marine wildlife species.

Whale-watching pressure in the Juneau area has been steadily increasing over the last two decades, as the whale-watching industry has grown to include a high number of whale-watching vessels and associated vessel noise (A. Jensen, personal communication[2]). There are now growing concerns for the sustainability of the whale-watching industry near Juneau because of the increase in disturbance to whales in the area. The Juneau tour area is relatively small, roughly 30 km by 15 km and part of an archipelago system made up of narrow passageways between islands. During the summer season, there are between 2-30 whales foraging in the tour area, typically clustered in hot spots, where prey is presumed to be abundant. In 2016, there were 60 tour boats operating out of Juneau's main port, Auke Bay, that participated in whale-

[2] Aleria Jensen. PO BOX 21668, Juneau, Alaska, 99802-1668, Alaska Region, National Marine Fisheries Service. February 2016.

watching (both whale-watching-specific and charter fishing boats; Teerlink, unpublished data). At times when there are many whales dispersed throughout the area, the whale-watching effort can be distributed among whales. However, when whale abundance is low or highly aggregated, it is common for up to 30 whale-watching, charter, and recreational craft to follow a single group of whales. This is especially true for groups of whales engaged in coordinated bubble-net feeding activity. These large aggregations make for particularly exciting whale-watching and tour and recreational boats rarely pass up the opportunity to stop and watch, even if it means sharing the space with several other boats. Consequently, bubble net feeding groups are often surrounded by dozens of vessels and associated vessel noise throughout the day during the extent of the tour season (Teerlink, unpublished data).

There are four objectives of this study:

1) To assess the effect of tissue type (skin versus blubber) and sample weight on steroid hormone concentration measured
2) To evaluate chronic stress response from vessel disturbance
3) To evaluate sex steroid hormones
4) To assess progesterone as an indicator of pregnancy status

Objective (1) is an attempt to better understand the tissue and sample weight required to gather reliable data on steroid hormone concentrations to make the best use of small biopsy samples. This information is important to understand if the skin from biopsy samples and small tissue samples can be useful in analyses. Objective (2) is the main objective for this study and is to determine if there is evidence of a long-term, physiological stress response to the high vessel densities and associated vessel noise found in humpback whales in the Juneau area during the summer tour season. We hypothesized that cortisol in blubber is positively correlated with the amount of vessel traffic in the 3-4 months leading up to sampling, and therefore, would be significantly higher in Juneau area whales in late summer than in whales from other areas at the same time of year. For this study, we sampled humpback whales in the Juneau tour area and compared their cortisol concentrations to whales in Stephens Passage in Southeast Alaska and Kodiak Island and Shumagin Islands in the western Gulf of Alaska, all areas with far less vessel traffic. Because blubber reflects longer-term averaged steroid hormone levels, we believe that measuring blubber cortisol concentrations is a unique way to evaluate long-term stress response from persistent vessel presence relative to “normal” baseline stressors experienced by all whales. For objective (3), we measured several sex steroid hormones (progesterone, testosterone, and estradiol) in our samples. We expected that sex and life history status could affect cortisol levels, as is seen in other studies (*e.g.*, Steinman et al. (2015)), but do not have data on sex, maturity, and reproductive status of whales sampled for this study. *In lieu* of these data, we evaluate sex steroid hormone concentrations. And finally, for objective (4), we assessed progesterone concentration as an indicator of pregnancy status and used later sighting histories to verify these results.

Methods

Photo Identification

Humpback whales in this study were tracked using photo identification. Humpback whales are individually identifiable by the unique combination of shape, pigmentation, and scarring on their ventral fluke surface that is visible when a whale descends on a sounding dive (Katona and Whitehead 1981). The process of photographing these markings is a trusted and cost effective method for obtaining sighting histories to track individual humpback whales (Calambokidis et al. 2008; Friday and Smith, 2000; Katona and Whitehead, 1981; Straley et al. 2008; Teerlink et al. 2015).

Photo identifications were collected on regular surveys of the tour area from May – September during 2014, and by a subset of whale-watching industry participants that collected fluke photographs on their tours and submit them to us as part of a citizen science program (Teerlink et al. *in review*). The combined pool of photo identifications provides sighting history data that were used to identify the individual humpback whales being sampled, identify whales that use the Juneau area and are therefore exposed to high densities of whale-watching traffic, provide relevant information on life history, and help to avoid inadvertently double sampling the same individual whale.

Field Methods and Study Design

During 2014, biopsy samples were collected from whales in the Juneau tour area (*n*=17) and control areas with far less vessel traffic: Stephens Passage in Southeast Alaska (*n*=11) and the western Gulf of Alaska (*n*=19; Table 2.1; Fig. 2.1). In Stephens Passage, samples were collected from whales in the southern extent in Seymour Canal and Gambier Bay. This area is geographically close to Juneau (~ 115km south), but has far less vessel traffic, mostly limited to occasional recreational boaters. In the western Gulf of Alaska, samples were taken near Kodiak Island (*n*=12) and Shumagin Islands (*n*=7), which are geographically farther from Juneau (~ 1,200 km), but found at similar latitude to the Southeast Alaska sites (Fig. 2.1). The vessel traffic near Kodiak Island and Shumagin Islands is much lower than in the Juneau area and is generally limited to fishing, shipping, and recreational vessels (little or no whale-watching tourism). Samples from Southeast Alaska (Juneau and Stephens Passage) were collected specifically for this study (authorized by the University of Alaska Institutional Animal Care and Use Committee # 474034-1 and 642456-2), and samples from the western Gulf of Alaska (Kodiak Island and Shumagin Islands) were taken from tissue archives (Witteveen et al. 2015).

Remote biopsy sampling is a commonly used field method in marine mammal research and has been practiced for over 30 years to collect tissue samples (*e.g.*, Aguilar and Nadal 1984; Witteveen et al. 2011). Studies measuring cetacean responses to biopsy sampling indicate that any adverse effects are minimal (Noren and Mocklin

2012). Biopsies were collected *via* a modified 0.22 rifle (PneauDart) that shoots an untethered dart with a biopsy-coring tip and collects a sample approximately 0.5 g and approximately 15 mm deep and 5 mm in diameter. Darts bounce off the animal (with the skin and blubber core sample intact) and float until they can be retrieved. There is some expected lipid loss as a result of the biopsy process (sampling effect; Ryan et al. 2013), but we assume that this is relatively consistent among biopsy-collected samples, regardless of sampling location. The amount of time a biopsy is in water can also impact the amount of lipid retained in a sample (Ryan et al. 2013; C. Allen, personal communication[3]). Biopsy samples used in this study were all collected in the same way with a relatively consistent retrieval time for all samples (1-2 min), and we believe any sampling effect or lipid loss from retrieval time to therefore have a minimal effect in our study. Biopsy samples were only taken from animals that had been photo identified, so that samples could be linked to individual sighting histories. Samples were stored within the biopsy dart tip in plastic bags on ice until return to the lab, where the sample could be removed from the dart, packaged in glass vials, and frozen at -80° C for later processing. Field and storage methods were the same for all samples in this study, including the archived samples. The only known difference between archived and recent samples is the amount of time they were stored. While duration of frozen storage varied, this factor had no impact on cortisol concentration in beluga whales (Trana et al. 2015b). Therefore, we do not believe that storage duration affected steroid hormone concentration in our study.

[3] Camryn Allen. 8901 La Jolla Shores Drive, La Jolla, CA 92037, Southwest Fisheries Science Center, National Marine Fisheries Service. December 2015.

We limited all biopsy sampling, including control areas, to late in the tourism season (August — early October), because this would theoretically reflect the whale-watching “treatment” exposure of the prior weeks and months (Kellar et al. 2013; Kershaw and Hall 2016). A summary of sighting histories of individual whales sampled in the Juneau area is given in Table 2.2. None of the whales sampled in control areas were seen in the Juneau area during this study (or *vice versa*), indicating that movement of individual whales among the experimental area and control areas was unlikely. We expect that any stress response from our research vessel approach and/or biopsy collection was not reflected in blubber/skin samples because blubber steroid hormone levels are not thought to reflect of real-time circulating blood/serum levels, but rather of longer-term cumulative steroid hormone levels (Kellar et al. 2013; Kershaw and Hall 2016).

Laboratory Methods – Steroid Extraction and Analysis

While the focus of this study was the assessment of cortisol concentrations in humpback whale biopsy samples, we also measured the concentrations of three sex steroid hormones (testosterone, progesterone, and estradiol) in each sample to better understand steroid hormone compositions in the different study regions. Blubber and skin were subsampled to 0.2 g (+/- 0.025 g) from biopsy cores, and lipids were extracted from the subsample using a method modified from Hunt et al. (2006, 2014) and Wasser et al. (2000). The sample was added to 2.8 mL ceramic bead homogenizer cryovials, and 10 µL of deuterated hormone was added as internal standard for each of the four hormones evaluated: d_4-cortisol, d_9-progesterone, d_5-estrodiol, and $^{13}C_3$-testosterone. Then, 1,460 µL of 100% MeOH (methanol) was added to bring the solution to 2 mL. Vials were vortexed for 8 min, and then rocked for 24 hrs at room temperature. Homogenized samples were centrifuged for 20 min at 10,000 RPM before the supernatant was transferred to 2 mL glass vials, and the methanol was evaporated under nitrogen gas. Resulting lipid extract was sealed, frozen, and shipped in liquid nitrogen dry shippers to the Metabolite Profiling Facility at Purdue University, IN. There, each sample was reconstituted with 200 µL of methanol, then split into two equal aliquots and dried again using an Eppendorf-Vacufuge rotary evaporating device.

The first aliquot of each extract was derivatized with dansyl chloride (dansyl Cl) according to Zhang et al. (2009) to assess estradiol. To each sample, 20 µL of 10mM Na_2CO_3 and 50 µL of freshly prepared dansyl Cl solution (3 mg/mL acetone) was added. The samples were heated at 60°C for 10 min. Samples were transferred to autosampler vials and immediately analyzed. An Agilent 1200 Rapid Resolution Liquid Chromatography (LC) system coupled to an Agilent 6460 series QQQ Mass Spectrometer (MS) was used to analyze all samples *post* derivatization. For the dansyl Cl derivatives, the following conditions were used with a Waters Xbridge C18 2.1mm x 100mm, 3 µm column for LC separation: Buffers were (A) water + 0.1% formic acid and (B) acetonitrile + 0.1% formic acid. The linear LC gradient was as follows: time 1 min=90% A and 10% B, time 5 min=0% A and 100% B, time 15 min=0% A and 100% B, time 15.5 min=90% A and 10% B, time 18 min=90% A and 10% B. The flow rate of buffers through the High Performance Liquid Chromatography (HPLC) column was 0.3

mL/min. Multiple Reaction Monitoring (MRM) was used to target the specific steroid hormones of interest. Data were acquired in positive Electrospray Ionization (ESI) mode by monitoring the following transitions in atomic mass: Estradiol (dansyl Cl) 506.1→171 (30V), 155.8 (40V); d_5-Estradiol (dansyl Cl) 511.1→171 (30V), 155.8 (40V); and Estriol (dansyl Cl) 522→171 (30V), 155.8 (40V). The ESI interface had a gas temperature of 325°C, gas flow rate of 8 L/min, nebulizer pressure of 45 psi, sheath gas temperature of 250°C, sheath gas flow rate of 7 L/min, capillary voltage of 3,500 V, and nozzle voltage of 1,500 V.

The second sample aliquot was derivatized with the AB Sciex Keto derivatization kit (AB Sciex, Framingham, MA) to assess testosterone, cortisol, and progesterone. To each sample, 50 µL of reagent was added. The reaction time was 60 min at room temperature. The samples were transferred to autosampler vials and immediately analyzed. An Agilent Zorbax 80Å Extend-C18 4.6mm x 150mm, 5 µm column was used with the buffers (A) water + 0.1% formic acid and (B) acetonitrile + 0.1% formic acid. The linear LC gradient was the same as for the first aliquot. MRM was used to target the specific steroid hormones of interest. Data were acquired in positive ESI mode by monitoring the following transitions in atomic mass: Testosterone 403.1→344.1 (20V), 164 (40V); $^{13}C_3$-Testosterone 406.1→347.1 (20V), 167 (40V); Cortisol 477.1→418.3 (15V), 388.2 (35V); d_4-Cortisol 481.1→422.3 (15V), 392.3 (35V); Progesterone 429.1→370 (20V), 126 (30V); and d_9-Progesterone 438.1→379 (20V), 132 (30V). The jet stream ESI interface had a gas temperature of 325°C, gas flow rate of 8 L/min, nebulizer pressure of 45 psi, sheath gas temperature of 250°C, sheath gas flow rate of 7 L/min, capillary voltage of 4,000 V, and nozzle voltage of 1,000 V.

Extraction efficiency was evaluated by comparing known volumes of deuterated internal standards (and without added sample) that had been through the extraction process (n=8, “Blank - Extracted”) with the same volume of deuterated internal standard that had not been through the extraction process (n=5, “Blank - Not Extracted”). The percent of deuterated internal standard recovery was the ratio of average hormone concentration in the “Blank - Not Extracted” samples and average hormone concentration in the “Blank - Extracted” samples. The extraction efficiencies for each hormone were as follows: cortisol=71.5%, testosterone=107.4%, progesterone=51.1%, estradiol=79.4%. Extraction efficiencies are provided for reference, results were not altered to correct for inefficiencies in extraction. Steroid hormone measurements are reported as concentrations, ng/g (divided by the wet adipose mass of the extracted sample).

Effect of Tissue Type and Sample Weight

Size and composition (skin *versus* blubber) of tissue samples collected with biopsy can sometimes be a limiting factor in analyses, particularly if biopsy samples are being used for multiple laboratory analyses. Therefore, it is valuable in steroid hormone analyses to understand if skin can be used interchangeably with blubber, and if smaller tissue subsamples can also be reliable. We analyzed tissue from eight humpback whales that stranded from 2007 — 2014. These samples were collected from recently dead humpback whales found in Alaskan waters; the Alaska Marine Mammal Stranding Network tissue archives provided six of these samples, and two were provided by the University of Alaska Museum tissue archives (UAM ID: 30552 and 30661). Where possible, two subsamples of 0.2 g blubber were compared with one subsample of 0.1 g blubber, one subsample of 0.05 g blubber, and one subsample of 0.2 g skin to assess consistency in cortisol concentration. To increase our statistical power in interpreting differences in skin *versus* blubber, we compared tissue types after including data from biopsy samples, where both tissue types were available. This increased our paired blubber-skin sample size from 4 whales (stranded only) to 34 whales (both stranded and biopsied whales). For all comparisons, we used linear mixed effects models to test for differences in cortisol concentration among tissue sample sizes and types across animals. Variability in cortisol concentrations among whales (*i*) and sample size/type (*k*) increases as concentrations increase, suggesting multiplicative errors. Therefore, cortisol concentrations were log-transformed to normalize the residuals and equalize variances:

(a) $$\log(Cortisol\ Concentration)_{k,i,j} = \alpha_k + a_i + \varepsilon_{k,i,j}$$

(b) $$a_i \sim N(0, \sigma_a)$$

(c) $$\varepsilon \sim N(0, \sigma_\varepsilon)$$

where $\propto_k$ is the mean of the log-transformed cortisol concentration for sample weight or tissue type *k*, a_i is a random effect reflecting among-whale difference in average cortisol concentration, and $\varepsilon_{k,i,j}$ represents within-whale residuals for sample *j*.

Evaluation of Chronic Stress Response from Vessel Disturbance

Cortisol concentrations were compared pairwise between collection areas using two sample t-test at a significance level of ∝=0.05 to evaluate potential chronic stress response from vessel disturbance in Juneau whales compared with whales from control areas. An *ad hoc* power analysis was conducted to assess statistical power given sample sizes. Effect size (*d*) was estimated using:

$$d = \frac{\bar{x}_a - \bar{x}_b}{\sqrt{\frac{\sigma_a^2 + \sigma_b^2}{2}}}$$ (Rosnow and Rosenthal 1996).

Juneau area trends in cortisol concentration were further investigated by correlating cortisol concentration for each individual whale with the total number of sightings of that animal prior to sampling (a proxy for relative exposure to high vessel “treatment”) with a Pearson’s Linear Correlation at a significance level of ∝=0.05.

Evaluation of Sex Steroid Hormones

We analyzed additional steroid hormones to assess potential site-specific differences in demographics of sampled individuals. Data on sex, maturity, and pregnancy status of individual animals sampled were not available, however, these factors could influence cortisol concentrations and confound our results. Testosterone, progesterone, and estradiol are sex hormones that vary with life history status and were used as *ad hoc* measures to determine if our samples had an equal representation of life history status among regions. Hormone concentrations from all samples were tested for correlations in a pairwise analysis. Both Pearson correlation coefficients and Spearman rank correlation coefficients were generated for each pairwise comparison. The ranked analysis was included to eliminate the bias that outliers may have on coefficients. Estradiol was removed from all analyses, as more than half of the sample concentrations were below the detection threshold (approximately 75 ng/g). Spatial patterns in testosterone and progesterone concentrations were then evaluated to reveal potential bias in life history status of sampled whales. These comparisons were done using one-way ANOVA at a significance level of α=0.05, as was done for analysis of cortisol concentrations. Where necessary, ANOVAs were followed up with Tukey's Honest Significance Difference (HSD) to indicate the relative contributions between area pairs. We would expect that progesterone would be substantially elevated in pregnant whales (*e.g.*, Kellar et al. 2013), which may complicate any correlations. To eliminate the bias that these "outliers" would have in evaluating regional differences in progesterone, we also ran a one-way ANOVA using ranked data.

Progesterone as an Indicator of Pregnancy Status

Progesterone is a steroid hormone associated with pregnancy, and blubber progesterone concentrations have been shown to be indicative of pregnancy for free-ranging cetaceans (Kellar et al. 2006, 2013; Pérez et al. 2011; Trego et al. 2013). Progesterone concentrations from each sample were compared with the mean using a modified Thompson tau technique (Thompson 1935) to identify statistically significant outliers, which could be indicative of pregnancy during the time of sampling. Sighting histories from the following year (2015) were examined for data on calf presence to verify pregnancy status in whales with progesterone levels identified as outliers.

Results

Effect of Tissue Type and Sample Weight

Cortisol concentrations were not different between blubber and skin, nor did low sample weight impact concentrations (Fig. 2.2). Cortisol extracted from blubber samples of different weights (0.2 g, 0.1 g, and 0.05 g) from the same whale showed no significant difference (ANOVA: F=1.09, P=0.36). When we evaluated blubber *versus* skin (using all samples of blubber, regardless of weight and both stranded and biopsy whales; n=34), we found no significant difference between paired blubber and skin (ANOVA: F=1.66, P=0.20; Fig. 2.3).

Evaluation of Chronic Stress Response from Vessel Disturbance

Cortisol concentrations from samples varied among regions (F=12.3, P<0.001). However, cortisol concentrations of samples from the Juneau whales were not higher than those from control areas. In particular, there was no significant difference (t-test: t=1.2, P=0.23) in mean cortisol concentration between the treatment area, Juneau, and the nearby Southeast Alaska control area, Stephens Passage (observed difference 4.3 ng/g (LCI=-2.5 ng/g UCI=11.1 ng/g; Table 2.3). The associated statistical power was 0.26, given an estimated effect size of 0.5. However, humpback whales in the western Gulf of Alaska had significantly higher tissue cortisol concentrations than whales in Southeast Alaska (t-test: t=-5.0 P<0.001; observed difference = 39.9 +/-15.7 ng/g (95% CI); Fig. 2.4). The associated statistical power was 1.00, given an estimated effect size of 4.4. Cortisol concentration was not significantly correlated with the frequency of Juneau area sightings (Pearson's Linear Correlation: R=0.29, *P*=0.24).

Evaluation of Sex Steroid Hormones

Significant positive correlations were found between each pair of steroid hormones analyzed using both the Pearson correlation coefficients and the Spearman rank correlation coefficients (Table 2.4). There were no regional differences in testosterone concentration among regions (ANOVA: F=0.873, *P*=0.46). Progesterone concentration, however, did vary by region, seen both with actual concentration values (ANOVA: F=5.04, *P*=0.004) and with ranked data (ANOVA: F=6.95, *P*=0.001). The

Tukey's HSD results indicate that this difference is driven by differences between Shumagin Islands and Stephens Passage (Table 2.5).

Progesterone as an Indicator of Pregnancy Status

Progesterone concentrations were high in three whales sampled. The concentrations of the three outliers were as follows: ID 1879 (Juneau area)=205.4 ng/g, ID 2171 (Juneau area)=204.5 ng/g, and SDP07-05 (Shumagin Islands)=217.1 ng/g. For comparison, the remaining samples had a mean progesterone concentration of 78.6 (+/- 33.6 ng/g; Table 2.3). From analyzing sighting histories of the whales sampled in this study and later identified in 2015, we learned that Juneau area whale ID 1879 has a calf (the other two whales with high progesterone were not re-sighted) and no calves were seen with any other whales sampled in 2014.

Discussion

The main purpose of this study was to determine if humpback whales, subjected to high densities of whale-watching vessel traffic, expressed physiological signs of increased stress response compared with whales in more remote regions. We hypothesized that humpback whales that are exposed to high whale-watching pressure would have significantly higher cortisol concentrations in their blubber toward the end of the tour season than whales in areas with low vessel traffic. We compared samples from humpback whales during August, September, and late October near Juneau (high whale-watching) with control areas: Stephens Passage in southeastern Alaska, and Kodiak Island and Shumagin Islands in western Gulf of Alaska. We found no difference in tissue cortisol concentrations between samples collected in Juneau and Stephens Passage, but did find significantly higher levels in samples from the western Gulf of Alaska (Kodiak Island and Shumagin Islands), indicating that there is no evidence for cumulative elevated cortisol levels in whales sampled from areas with high levels of whale-watching. However, regional differences (*i.e.*, higher cortisol concentrations in the western Gulf of Alaska) are considered in the discussion below.

Effect of Tissue Type and Sample Weight

Our results indicate that there may be flexibility in the tissue type and size of sample used for steroid hormone analysis. Biopsy samples are occasionally incomplete, meaning small or skin-only samples. Our results show that smaller (0.1 g and 0.05 g) blubber samples produce comparable measures of cortisol concentration and are therefore reasonable to use in place of 0.2 g blubber samples. This is consistent with other studies that have yielded measurable steroid hormones from very small amounts of sample (Hogg et al. 2009; Hunt et al. 2013; Thompson et al. 2014). Studies have successfully detected steroid hormones from small amounts (0.03-0.05 mg) of cetacean mucus in blow samples (Hogg et al. 2009; Hunt et al. 2013; Thompson et al. 2014), from 0.2 g bone samples with <7% associated lipid (Charapata 2016), and small samples of keratinized tissue (*e.g.*, hair (Accorsi et al. 2008; Bryan et al. 2013; Weisser et al. 2016), baleen (Hunt et al. 2014), nail (Warnock et al. 2010)). The utility of smaller blubber samples for steroid hormone analysis allows for further subsampling of whale biopsies for replication, archiving, or for other tissue analyses, reducing necessary biopsy effort.

Our study further suggests that skin can be used interchangeably with blubber for steroid hormone analysis. Recently, blubber has been targeted for steroid hormone analysis because it is assumed that lipophilic steroid hormones are preferentially stored in the lipid-rich blubber stores of a marine mammal. Humpback whale skin also tends to be lipid-rich (Pfeiffer and Jones 1993), however, the lipid concentration relative to blubber is unknown. Further, little is known about the sequestration and turnover rates for either tissue, or if these rates are comparable between tissues. The turnover of stable isotopes in skin has been estimated for bottlenose dolphins (*Tursiops aduncus*) at 22-46 days, depending on diet (Browning et al. 2014). The turnover rate of the skin cells themselves is thought to be 70-75 days for beluga whales (St Aubin et al. 2011) and 73 days for bottlenose dolphin (Hicks et al. 1985), suggesting all tissue may be replaced in cetacean skin approximately every 10 weeks. If humpback whale skin regenerates at similar rates to beluga and bottlenose dolphin skin, and if stable isotope retention is any indication, we can assume that steroid hormone turnover in skin is on the order of multiple weeks. This estimate is similar, but on the low end of the “weeks to months” range suggested for hormone turn-over in bowhead whale blubber by Kellar et al. (2013). When we consider that adipose tissue is an organ that is partly responsible for steroid hormone production (not just storage), it makes the relationship between steroid hormone concentrations in blubber compared with serum, skin, etc., even more complex. In this study, hormone concentrations in skin were slightly lower, but not significantly different from blubber. Therefore, we conclude that skin can be used for steroid hormone analyses and can be compared with blubber. Use of skin could be applied in future studies to maximize the available tissue from a biopsy sample to be used for steroid hormone analysis, and allow researchers to make use of small or skin-only biopsies. To our knowledge, this is the first study on cetaceans that has measured steroid hormone concentrations in skin, and the first study to report consistency between blubber and skin steroid hormone concentrations. However, more studies are needed to enhance our understanding of tissue-specific turnover rates, and the role of blubber as an endocrine tissue.

Evaluation of Chronic Stress Response from Vessel Disturbance

We found no evidence to support our original hypothesis that humpback whales in the Juneau area have higher cortisol concentrations, relative to the other areas sampled, due to a stress response from chronic vessel disturbance, however, our sample sizes and statistical power to detect differences are low. Although the statistical power was low (0.26), the 95% CI included zero, therefore, we cannot rule out the possibility that there is no difference between groups. Further, other studies, for example Trana et al. (2015a), that document cortisol differences between populations report large differences in means (~7x) and a high percentage of non-overlap between groups, which is indicative of high effect sizes (~1.7; Cohen 1988). If effect sizes are high for identifying biologically significant differences in mean cortisol concentrations, lower samples sizes may be acceptable. We saw small differences in means (4.3 ng/g) and low percentages of non-overlap (7%) between Juneau and Stephens Passage samples. However, when Southeast Alaska samples were pooled and compared to the western Gulf of Alaska, we saw large differences in the means (39.9 ng/g) and high percentages of non-overlap (29%). So, while we have low statistical power between Southeast Alaska sites, there are no obvious (large) differences in blubber cortisol concentration means between Juneau and Stephens Passage, and the estimated effect size (0.5) may not be biologically significant.

When we looked specifically at samples from Juneau area whales, we saw no indication that frequency of sightings was correlated with cortisol concentration (P=0.24). However, we acknowledge that our sample sizes are low and variability in samples is high, and it would be difficult to confidently draw conclusions on this correlation.

Given our findings, we conclude that Juneau area humpback whales are likely habituated to vessel presence. We define habituation as in Cyr and Romero (2009): "…with repetition the animal learns to perceive that stimulus as innocuous, and thus reduces the intensity of their stress response to that particular stimulus." Anecdotally, humpback whales in the Juneau area are less skittish of boats compared with other areas. Indeed, whales appear to be quite comfortable moving and feeding among boats in this area, and it is not uncommon to have whales surface within a few feet of vessels and continue feeding even as more and more boats move into an area (J. Moran, personal communication[4]). In a study of whale reactions to vessel disturbance, Watkins (1986) noted that humpback whales near Cape Cod became habituated to tour boat activity. These authors reported that whales' reactions to boats changed from "negative," where whales abruptly changed behavior and evaded close interaction with boats, to "positive," where whales would permit close approaches and even appear to be curious of boats, while continuing to vocalize. These behavior changes, or habituation to vessel disturbance, occurred quickly – "Sometimes only a few encounters were needed to transform a whale's wariness to apparent unconcern" (Watkins 1986). Given the regional differences in cortisol concentration found, we believe adrenal exhaustion is unlikely, where adrenals become so over-stimulated that they no longer produce the cortisol (Cadegiani and Kater 2016), and that whales in this area are more likely not perceiving vessel disturbance as a threat and thus not eliciting a stress response. Therefore, the lack of elevated cortisol signal indicates that whales feeding in the Juneau area do not exhibit a chronic physiological response to vessel disturbance due to habituation.

Habituation in Juneau area humpback whales does not necessarily mean that whale-watching practices are benign. First, habituation can be problematic for wild animals, as it tends to make them less cautious of humans and vessels and could lead to a higher susceptibility to collisions and propeller strikes (Watkins 1986; Bejder and Samuels 2003; Cyr and Romero 2009; Harris et al. 2012). Second, while we did not find evidence of a chronic stress response in whales in the Juneau area, we suspect that not

[4] John Moran. 17109 Point Lena Loop Road, Juneau, AK 99801 Alaska Fisheries Science Center, National Marine Fisheries Service. May 2015.

all whales are habituated to high boat densities. Tolerance to vessel disturbance is likely variable by individual, and whales likely retreat to outlying areas with less boat traffic when they become uneasy. Bottlenose dolphin, for example, evade tour boats when vessel densities exceed thresholds (Pérez-Jorge et al. 2016). In this scenario, whales would not be accumulating cortisol in their tissues as a result of high vessel disturbance, because they simply leave the area (and therefore the stimulus). In our study area, this is supported by anecdotal observations during times of low whale abundance, where the whales present appeared to be limited to the ones most commonly seen in the tour area. In total, 70-85 individual humpback whales are seen near Juneau each year. Of these, half are transient, moving into and out of the area within a few days. However, the other half exhibits varying degrees of site fidelity; including approximately 15 whales that are seen regularly (10 or more sightings per season) and have high inter-annual site fidelity, reliably returning to the Juneau area each summer after their tropical migration (Teerlink, unpublished data). Intuitively, whales with the highest site fidelity should have the most experience feeding among high vessel densities, and are more likely to be habituated. In the absence of knowledge on tolerance of individual whales to vessel disturbance, we advise a precautionary approach to tourism and boat traffic increase. We also recommend continued studies to monitor whales under the existing whale-watching levels to ensure sustainability in industry practices, particularly at times when whale abundance is low or whales aggregate, which then can cause increased vessel crowding.

While there might not be a physiologic stress response elicited, vessel presence and associated noise could still be impacting whales in this area. Humpback whales are highly sensitive to acoustics, even while in Alaska, relying on hearing to communicate and locate prey (Stimpert et al. 2011; Fournet et al. 2015). Sound masking from high boat concentrations could limit the foraging efficiency of humpback whales and interrupt social interactions (Stimpert et al. 2011; Erbe et al. 2015; Fournet et al. 2015) in a way that is impactful, but not detectable by cortisol concentrations. Humpback whales reduce their vocalizations in the presence of vessel noise (Dunlop 2016) or increase the amplitude and frequency of vocalizations (Lombard effect) while in a noisy environment (Dunlop et al. 2014). Similarly, a Lombard effect in response to boat noise has been found in a variety of other cetacean species (Foote et al. 2004; Scheifele et al. 2005; Parks et al. 2011; Erbe et al. 2015). Increases in whale call volume in response to anthropogenic noise can have unforeseen long-term negative energetic effects.

Our results indicate differences in cortisol concentration between Southeast Alaska and western Gulf of Alaska samples that may reveal regional differences in steroid hormone levels. Humpback whales sampled in the western Gulf of Alaska had significantly higher levels of cortisol than did their Southeast Alaska counterparts. Samples from the western Gulf of Alaska were collected by different researchers, but the methods and equipment were the same. The only difference is in the years that they were collected and the storage duration. We do not have comparison samples from Southeast Alaska for earlier years. However, we do not see a temporal trend in the western Gulf of Alaska data and interpret this to mean that the higher tissue cortisol concentrations in western Gulf of Alaska were not a result of the collection method or years of collection. Further, blubber hormone concentrations in beluga blubber did not change over time in frozen storage (Trana et al. 2015b); therefore, we do not expect that storage time had a measurable impact on the amount of lipid or steroid hormone collected in each sample in this study.

The cause of higher cortisol concentrations in humpback whales in the western Gulf of Alaska (Kodiak and Shumagin Islands) is unknown. It could be due to differences in prey resources, less favorable environmental conditions, increased predation threat, or some other unknown factor(s). However, data on prey availability and humpback whale prey preferences were collected in these areas during the years when biopsy samples were taken, and there is no evidence to suggest limited prey quantity or quality (Witteveen et al. 2015; Wright et al. 2015, 2016). Further, transient killer whales (the only predator of humpback whales in Alaskan waters) are common in both Southeast Alaska (Dahlheim and White 2010) and western Gulf of Alaska (Zerbini et al. 2007). That said, humpback whales are not considered to be regular killer whale prey in Southeast Alaska (Dahlheim and White 2010), whereas in the western Gulf of Alaska, gray whale (*Eschrichtius robustus*) calves (similarly sized to humpback whales) are a regular target prey for killer whales (Matkin et al. 2007). It is possible that killer whales could be more of a threat, and potentially chronic stressor, to humpback whales in the western Gulf of Alaska than in Southeast Alaska, but that there are fewer observers in this area to document attacks. Both Southeast Alaska and western Gulf of Alaska are predominantly comprised of Hawaii Distinct Population Segment individuals

(94% and 89%, respectively; Wade et al. 2016), a management unit used by National Marine Fisheries Service which is considered healthy (not listed as threatened or endangered under the Endangered Species Act). Therefore, it is unlikely that the regional differences in cortisol concentration are indicative of underlying differences in stock status.

The statistical difference in cortisol concentration detected between regions may not be biologically significant. Other studies of marine mammal blubber cortisol concentrations show much wider ranges. For example, Trana et al. (2015a) documented 7-fold increase in cortisol concentration in ice-entrapped beluga whales. Harbor seal blubber cortisol concentration increases by two orders of magnitude when they molt (Kershaw and Hall 2016). In contrast, the regional average cortisol concentrations documented here for humpback whale blubber was only, at most, two-fold different between regions. Therefore, it is important that future studies continue to investigate humpback whale blubber cortisol concentrations to provide baseline data on regional variability and determine what levels of variation in cortisol concentration are biologically significant.

Evaluation of Sex Steroid Hormones

Testosterone and progesterone concentrations were analyzed as a proxy for sex, maturity, and reproductive status. Concentrations of testosterone, progesterone, and cortisol were significantly positively correlated in pairwise analyses. Because testosterone is known to be higher in males than females (Kellar et al. 2009; Vu et al. 2015), but did not vary by region in our samples, we interpret this finding to indicate that there was no sampling bias toward males among the regions. Progesterone, however, did vary by region. Even when progesterone concentration data were ranked to eliminate the "outlier" effect of pregnant individuals (discussed in further detail below), cortisol and progesterone were correlated, and regional differences in progesterone concentration were apparent. This difference was primarily driven by higher progesterone concentration in Shumagin Islands versus Stephens Passage (Table 2.3, 2.5). These differences could indicate that pregnancy and/or female maturity was not equally represented in the samples collected among regions. Progesterone is higher in mature females than in immature females or males (Kellar et al. 2013). We did not see testosterone differences among regions, but did see differences in progesterone between the two areas, suggesting that Shumagin Island samples over-represent mature and (potentially) pregnant females. Cortisol covaries with progesterone, and may be a confounding factor in our analysis. However, while this could be a confounding factor that could explain elevated cortisol in Shumagin Islands (where progesterone concentration was highest), it cannot explain elevated cortisol concentrations in the Kodiak region (where progesterone concentrations are not elevated relative to the other areas in this study). Therefore, we believe that the regional patterns in cortisol concentration discovered in this study are actually present, and not confounding factors caused by differences in life history status among sampling areas.

Progesterone as an Indicator of Pregnancy Status

Progesterone concentrations were particularly high in three whales sampled, and could be indicative of pregnancy for these individuals. Progesterone concentrations were nearly 3x higher in samples from these whales compared with the other samples. Samples were collected in 2014, and if the whales were, in fact, pregnant, and the pregnancy yielded successful reproduction, we would expect to see these animals with a calf in 2015 (assuming the calf survived). Two of these whales (ID 2171 and SDP07-05) were not seen again in 2015, so visual verification of successful breading could not be determined. However, ID 1879 was resighted near Juneau many times in 2015 and was consistently accompanied by a calf. Further, of the other whales sampled in this study that were re-sighted in 2015, none were seen with a calf. This indicates that we were able to validate prior pregnancy in one whale with “anomalously” high progesterone concentration, and have no data from our subsequent sightings of whales with low progesterone levels that would indicate false-negatives on pregnancy status. These findings suggest that progesterone analysis from biopsy tissue samples can be useful for indicating pregnancy status in humpback whales and is consistent with other studies, where cetacean blubber progesterone concentrations were substantially elevated in pregnant individuals (Mansour et al. 2002; Kellar et al. 2006, 2013; Pérez et al. 2011; Trego et al. 2013). The only other study, to our knowledge, that evaluates progesterone in humpback whales is Clark et al. (2016). Here, elevated progesterone levels were found in many of their samples, but direct confirmation through later sightings was not possible.

Conclusions

To our knowledge, this is the first study to measure cortisol concentrations as a way of evaluating chronic impacts from whale-watching, to evaluate the use of cetacean skin for hormone analyses, or to validate progesterone as an indication of pregnancy status in humpback whales. We did not find evidence to support our hypothesis that there would be a correlation between cortisol concentration and vessel traffic, however, our samples sizes and statistical power were low. Nonetheless, this finding may be indicative of habituation to vessel traffic in this area. We show that skin and blubber steroid hormone levels are similar and may be comparable and/or interchangeable in analyses. Lastly, this study supports use of blubber progesterone concentrations as an index of pregnancy status from biopsy samples of free-ranging humpback whales.

Acknowledgements

This project was funded by the NSF Marine Ecosystem Sustainability in the Arctic and Subarctic (MESAS) IGERT program (#DGE-0801720) and the North Pacific Research Board (G8728). Thank-you the Alaska Marine Mammal Stranding Network and the University of Alaska Museum for access to tissue samples. We gratefully acknowledge A. Jannasch and the Purdue University Bindley Bioscience Center, and P. Charapata and N. Farnham at the University of Alaska Fairbanks for their help with laboratory analyses. Additional thanks to L. Short-Forrer, K. Coutre, B. Williams, and B. Mecum for assistance with fieldwork. Thank-you to D. DeMaster, F. Mueter, and A. Beaudreau for their help in shaping the study design, analysis, and editorial comments.

Photographs and biopsy samples collected for this study were taken under NMFS Scientific Research Permit #14296.

References Cited

Accorsi PA, Carloni E, Valesecchi P, Viggiani R, Gameroni M, Tamanini C, Seren E (2008) Cortisol determination in hair and faeces from domestic cats and dogs. Gen Comp Endocrinol 155:398–402

Aguilar A, Nadal J (1984) Getting hypodermic biopsies from free-ranging cetaceans. Investig Pesq 1:23–29

Alaska Department of Commerce, Community and Economic Development (2012) Alaska Visitor Statistics Program VI. McDowell Group.

Argüelles MB, Coscarella M, Fazio A, Bertellotti M (2016) Impact of whale-watching on the short-term behavior of Southern right whales (*Eubalaena australis*) in Patagonia, Argentina. Tour Manag Perspect 18:118–124

Atkinson S, Crocker D, Houser D, Mashburn K (2015) Stress physiology in marine mammals: How well do they fit the terrestrial model? J Comp Physiol B 185:463–486

Avila IC, Correa LM, Parsons ECM (2015) Whale-watching activity in Bahía Málaga, on the Pacific coast of Colombia, and its effect on humpback whale (*Megaptera Novaeangliae*) behavior. Tour Mar Environ 11:19–32

Bejder L, Samuels A (2003) Evaluating the effects of nature-based tourism on cetaceans. In: Gales N, Hindell M, Kirkwood R (eds) Fisheries, Tourism and Management issues, 1st edn. Collingwood, Australia, p 229–256

Blair HB, Merchant ND, Friedlaender AS, Wiley DN, Parks SE (2016) Evidence for ship noise impacts on humpback whale foraging behaviour. Biol Lett 12:5

Browning NE, Dold C, I-Fan J, Worthy GAJ (2014) Isotope turnover rates and diet-tissue discrimination in skin of ex situ bottlenose dolphins (*Tursiops truncatus*). J Exp Biol 217:214–21

Bryan HM, Adams AG, Invik RM, Wynne-Edwards KE, Smits JEG (2013) Hair as a meaningful measure of baseline cortisol levels over time in dogs. J Am Assoc Lab Anim Sci 52:189–96.

Burgess E a, Blanshard WH, Barnes AD, Gilchrist S, Keeley T, Chua J, Lanyon JM (2013) Reproductive hormone monitoring of dugongs in captivity: detecting the onset of sexual maturity in a cryptic marine mammal. Anim Reprod Sci 140:255–67

Cadegiani FA, Kater CE (2016) Adrenal fatigue does not exist: a systematic review. BMC Endocr Disord 16:48

Calambokidis J, Falcone EA, Quinn TJ, Burdin AM, Phillip J, Ford JKB, Gabriele CM, Leduc R, Mattila D, Rojas-Bracho L, Straley JM, Taylor BL, Urbán JR, Weller D, Witteveen BH, Yamaguchi M, Bendlin A, Camacho D, Flynn K, Havron A, Huggins J, Maloney N (2008) SPLASH : Structure of populations, levels of abundance and status of humpback whales in the North Pacific. Seattle, WA

Campana I, Crosti R, Angeletti D, Carosso L, David L, Di-Méglio N, Moulins A, Rosso M, Tepsich P, Arcangeli A (2015) Cetacean response to summer maritime traffic in the western Mediterranean Sea. Mar Environ Res 109:1–8

Charapata P (2016) Back to the future: Pacific walrus stress response and reproductive status in a changing arctic. University of Alaska Fairbanks

Christiansen F, Rasmussen M, Lusseau D (2013) Whale watching disrupts feeding activities of minke whales on a feeding ground. Mar Ecol Prog Ser 478:239–251

Clark CT, Fleming AH, Calambokidis J, Kellar NM, Allen CD, Catelani KN, Robbins M, Beaulieu NE, Steel DJ, Harvey JT (2016) Heavy with child? Pregnancy status and stable isotope ratios as determined from biopsies of humpback whales. Conserv Physiol 4:1–13

Cohen J (1988) Statistical power analysis for the behavioral sciences. Erlbaum. Hillsdale, NJ

Corkeron PJ (1995) Humpback whales (*Megaptera novaeangliae*) in Hervey Bay, Queensland: Behaviour and responses to whale-watching vessels. Can J Zool 73:1290–1299

Cosentino AM (2016) Effects of whale-watching vessels on adult male sperm whales off Andenes, Norway. Tour Mar Environ 11:215–227

Culloch R, Anderwald P, Brandecker A, Haberlin D, McGovern B, Pinfield R, Visser F, Jessopp M, Cronin M (2016) Effect of construction-related activities and vessel traffic on marine mammals. Mar Ecol Prog Ser 549:231–242

Cyr NE, Romero LM (2009) Identifying hormonal habituation in field studies of stress. Gen Comp Endocrinol 161:295–303

Dahlheim ME, White PA. (2010) Ecological aspects of transient killer whales *Orcinus orca* as predators in southeastern Alaska. Wildlife Biol 16:308–322

Deslypere JP, Verdonck L, Vermeulen A (1985) Fat tissue: A steroid reservoir and site of steroid metabolism. J Clin Endocrinol Metab 61:564–70

Dunlop RA (2016) The effect of vessel noise on humpback whale, *Megaptera novaeangliae*, communication behaviour. Anim Behav 111:13–21

Dunlop RA, Cato DH, Noad MJ (2014) Evidence of a Lombard response in migrating humpback whales (*Megaptera novaeangliae*). J Acoust Soc Am 136:430–437

Dunstan J, Gledhill A, Hall A, Miller P, Ramp C (2012) Quantification of the hormones progesterone and cortisol in whale breath samples using novel, non-invasive sampling and analysis with highly-sensitive ACQUITY UPLC and Xevo TQ-S. Milford, MA

Erbe C, Reichmuth C, Cunningham K, Lucke K, Dooling R (2015) Communication masking in marine mammals: A review and research strategy. Mar Pollut Bull 103:15–38

Foote AD, Osborne RW, Hoelzel AR (2004) Whale-call response to masking boat noise. Nature 428:910

Fournet ME, Szabo A, Mellinger DK (2015) Repertoire and classification of non-song calls in Southeast Alaskan humpback whales (*Megaptera novaeangliae*). J Acoust Soc Am 137:1–10

Friday N, Smith T (2000) Measurement of photographic quality and individual distinctiveness for the photographic identification of humpback whales, *Megaptera novaeangliae*. Mar Mammal Sci 16:355–374

Harris K, Gende SM, Logsdon MG, Klinger T (2012) Spatial pattern analysis of cruise ship-humpback whale interactions in and near Glacier Bay National Park, Alaska. Environ Manage 49:44–54

Hicks BD, St Aubin DJ, Geraci JR, Brown WR (1985) Epidermal growth in the bottlenose dolphin, *Tursiops truncatus*. J Invest Dermatol 85:60–63

Hogg CJ, Rogers TL, Shorter A, Barton K, Miller PJO, Nowacek D (2009) Determination of steroid hormones in whale blow: It is possible. Mar Mammal Sci 25:605–618

Hunt K, Moore M (2013) Overcoming the challenges of studying conservation physiology in large whales: a review of available methods. Conserv Physiol 1:1–24

Hunt KE, Rolland RM, Kraus SD (2013) Detection of steroid and thyroid hormones via immunoassay of North Atlantic right whale (*Eubalaena glacialis*) respiratory vapor. Mar Mammal Sci 30:796–809

Hunt KE, Rolland RM, Kraus SD, Wasser SK (2006) Analysis of fecal glucocorticoids in the North Atlantic right whale (*Eubalaena glacialis*). Gen Comp Endocrinol 148:260–72

Hunt KE, Stimmelmayr R, George C, Hanns C, Suydam R, Brower H, Rolland RM (2014) Baleen hormones: a novel tool for retrospective assessment of stress and reproduction in bowhead whales (*Balaena mysticetus*). Conserv Physiol 2:1–12

Jelinski DE, Krueger CC, Duffus DA (2002) Geostatistical analysis of interactions between killer whales (*Orcinus orca*) and recreational whale watching boats. Appl Geogr 22:393–411

Katona SK, Whitehead HP (1981) Identifying humpback whales using their natural markings. Polar Rec (Gr Brit) 20:439–444

Kellar NM, Catelani KN, Robbins MN, Trego ML, Allen CD, Danil K, Chivers SJ (2015) Blubber cortisol: a potential tool for assessing stress response in free-ranging dolphins without effects due to sampling. PLoS One 10:e0115257

Kellar NM, Keliher J, Trego ML, Catelani KN, Hanns C, George JC, Rosa C (2013) Variation of bowhead whale progesterone concentrations across demographic groups and sample matrices. Endanger Species Res 22:61–72

Kellar NM, Trego ML, Marks CI, Chivers SJ, Danil K, Archer FI (2009) Blubber testosterone: A potential marker of male reproductive status in short-beaked common dolphins. Mar Mammal Sci 25:507–522

Kellar NM, Trego ML, Marks CI, Dizon AE (2006) Determining pregnancy from blubber in three species of *delphinids*. Mar Mammal Sci 22:1–16

Kershaw EE, Flier JS (2004) Adipose tissue as an endocrine organ. J Clin Endocrinol Metab 89:2548–2556

Kershaw JL, Hall AJ (2016) Seasonal variation in harbour seal (*Phoca vitulina*) blubber cortisol - A novel indicator of physiological state? Sci Rep 6:21889

King SL, Schick RS, Donovan C, Booth CG, Burgman M, Thomas L, Harwood J (2015) An interim framework for assessing the population consequences of disturbance. Methods Ecol Evol 6:1150–1158

Mansour AA, McKay DW, Lien J, Orr JC, Banoub JH, Oien N, Stenson G (2002) Determination of pregnancy status from blubber samples in minke whales (*Balaenoptera acutorostrata*). Mar Mammal Sci 18:112–120

Matkin CO, Barrett-Lennard LG, Yurk H, Ellifrit D, Trites AW (2007) Ecotypic variation and predatory behavior among killer whales (*Orcinus orca*) off the eastern Aleutian Islands, Alaska. Fish Bull 105:74–87

Meissner AM, Christiansen F, Martinez E, Pawley MDM, Orams MB, Stockin KA (2015) Behavioural effects of tourism on oceanic common dolphins, *Delphinus* sp., in New Zealand: The effects of markov analysis variations and current tour operator compliance with regulations. PLoS One 10:e0116962

Musi N, Guardado-Mendoza R (2014) Cellular endocrinology in health and disease. Elsevier

New LF, Hall AJ, Harcourt R, Kaufman G, Parsons ECM, Pearson HC, Cosentino AM, Schick RS (2015) The modeling and assessment of whale-watching impacts. Ocean Coast Manag 115:10–16

Nichols TA, Anderson TW, Širović A (2015) Intermittent noise induces physiological stress in a coastal marine fish. PLoS One 10:e0139157

Noren DP, Mocklin JA (2012) Review of cetacean biopsy techniques: Factors contributing to successful sample collection and physiological and behavioral impacts. Mar Mammal Sci 28:154–199

Parks SE, Johnson M, Nowacek D, Tyack PL (2011) Individual right whales call louder in increased environmental noise. Biol Lett 7:33–35

Pérez-Jorge S, Gomes I, Hayes K, Corti G, Louzao M, Genovart M, Oro D (2016) Effects of nature-based tourism and environmental drivers on the demography of a small dolphin population. Biol Conserv 197:200–208

Pérez S, García-López Á, Stephanis R, Giménez J, García-Tiscar S, Verborgh P, Mancera JM, Martínez-Rodriguez G (2011) Use of blubber levels of progesterone to determine pregnancy in free-ranging live cetaceans. Mar Biol 158:1677–1680

Pfeiffer CJ, Jones FM (1993) Epidermal lipid in several cetacean species: ultrastructural observations. Anat Embryol (Berl) 188:209–218

Quakenbush LT, Citta JJ, George JC, Small RJ, Heide-Jorgensen MP (2010) Fall and winter movements of bowhead whales (*Balaena mysticetus*) in the Chukchi Sea and within a potential petroleum development area. Arctic 63:289–307

Rolland RM, Hunt KE, Kraus SD, Wasser SK (2005) Assessing reproductive status of right whales (*Eubalaena glacialis*) using fecal hormone metabolites. Gen Comp Endocrinol 142:308–317

Rolland RM, Parks SE, Hunt KE, Castellote M, Corkeron PJ, Nowacek DP, Wasser SK, Kraus SD (2012) Evidence that ship noise increases stress in right whales. Proc Biol Sci 279:2363–8

Rosnow RL, Rosenthal R (1996) Computing contrasts, effect sizes, and counternulls on other people's published data: General procedures for research consumers. Psychol Methods 1:331-340

Ryan C, McHugh B, O'Connor I, Berrow S (2013) Lipid content of blubber biopsies is not representative of blubber in situ for fin whales (*Balaenoptera physalus*). Mar Mammal Sci 29:542–547

Sapolsky RM, Romero LM, Munck AU (2000) How do glucocorticoids influence stress responses? Integrating permissive, suppressive, stimulatory, and preparative Actions. Endocr Rev 21:55–89

Scarpaci C, Parsons ECM (2014) Recent advances in whale-watching research: 2012–2013. Tour Mar Environ 11:79–86

Scheifele PM, Andrew S, Cooper RA, Darre M, Musiek FE, Max L (2005) Indication of a Lombard vocal response in the St. Lawrence River beluga. J Acoust Soc Am 117:1486–1492

Senigaglia V, Christiansen F, Bejder L, Gendron D, Lundquist D, Noren D, Schaffar A, Smith J, Williams R, Martinez E, Stockin K, Lusseau D (2015) Meta-analyses of whale watching impact studies: Comparisons of cetacean responses to disturbance. Mar Ecol Prog Ser 542:251–263

Spreng M (2000) Possible health effects of noise induced cortisol increase. Noise Health 2:59–64

St Aubin DJ, Smith TG, Geraci JR (2011) Seasonal epidermal molt in beluga whales, *Delphinapterus leucas*. Can J Zool 68:359–367

Stamation KA, Croft DB, Shaughnessy PD, Waples KA, Briggs S V. (2010) Behavioral responses of humpback whales (*Megaptera novaeangliae*) to whale-watching vessels on the southeastern coast of Australia. Mar Mammal Sci 26:98–122

Steinman KJ, Robeck TR, O'Brien JK (2015) Characterization of estrogens, testosterone, and cortisol in normal bottlenose dolphin (*tursiops truncatus*) pregnancy. Gen Comp Endocrinol 226:102–112

Stimpert AK, Au WWL, Parks SE, Hurst TP, Wiley DN (2011) Common humpback whale (*Megaptera novaeangliae*) sound types for passive acoustic monitoring. J Acoust Soc Am 129:476–482

Straley JM, Quinn II TJ, Gabriele CM (2008) Assessment of mark-recapture models to estimate the abundance of a humpback whale feeding aggregation in Southeast Alaska. J Biogeogr 36:427–438

Teerlink SF, von Ziegesar O, Straley JM, Quinn TJ, Matkin CO, Saulitis EL (2015) First time series of estimated humpback whale (*Megaptera novaeangliae*) abundance in Prince William Sound. Environ Ecol Stat 22:345–368

Teerlink SF, Horstmann L, Witteveen B (*In Review*) Blubber and skin steroid hormone concentration to evaluate chronic stress response from whale-watching vessels in humpback whales near Juneau, Alaska. Submitted to *Endangered Species Research*.

Thompson WR (1935) On a Criterion for the Rejection of Observations and the Distribution of the Ratio of Deviation to Sample Standard Deviation. Ann Math Stat 6:214–219

Thompson LA, Spoon TR, Goertz CEC, Hobbs RC, Romano TA. (2014) Blow collection as a non-invasive method for measuring cortisol in the beluga (*Delphinapterus leucas*). PLoS One 9:e114062

Trana MR, Roth JD, Tomy GT, Anderson WG, Ferguson SH (2015a) Increased blubber cortisol in ice-entrapped beluga whales (*Delphinapterus leucas*). Polar Biol:DOI 10.1007/s00300-015-1881-y

Trana MR, Roth JD, Tomy GT, Anderson WG, Ferguson SH (2015b) Influence of sample degradation and tissue depth on blubber cortisol in beluga whales. J Exp Mar Bio Ecol 462:8–13

Trego ML, Kellar NM, Danil K (2013) Validation of blubber progesterone concentrations for pregnancy determination in three dolphin species and a porpoise. PLoS One 8:1–9

Trites AW, Bain DE (2000) Short- and long-term effects of whale watching on killer whales (*Orcinus orca*) in British Columbia. IWC Work Long-Term Effects Whale Watch Adelaide, Aust:10

Vu ET, Clark C, Catelani K, Kellar NM, Calambokidis J (2015) Seasonal blubber testosterone concentrations of male humpback whales (*Megaptera novaeangliae*). Mar Mammal Sci 31:1258–1264

Warnock F, McElwee K, Seo RJ, McIsaac S, Seim D, Ramirez-Aponte T, Macritchie KA, Young AH (2010) Measuring cortisol and DHEA in fingernails: A pilot study. Neuropsychiatr Dis Treat 6:1–7

Wasser SK, Hunt KE, Brown JL, Cooper K, Crockett CM, Bechert U, Millspaugh JJ, Larson S, Monfort SL (2000) A generalized fecal glucocorticoid assay for use in a diverse array of nondomestic mammalian and avian species. Gen Comp Endocrinol 120:260–275

Watkins WA (1986) Whale reactions to human activities in Cape Cod waters. Mar Mammal Sci 2:251–262

Weisser JJ, Hansen M, Björklund E, Sonne C, Dietz R, Styrishave B (2016) A novel method for analyzing key corticosteroids in polar bear (*Ursus maritimus*) hair using liquid chromatography tandem mass spectrometry. J Chromatogr B 1017–1018:45–51

Wingfield JC, Romero ML (2011) Adrenocortical responses to stress and their modulation in free-living vertebrates. In: McEwen. B.S., Goodman HM (eds) Handbook of Physiology. Oxford University Press, Oxford, p 211–236

Witteveen BH, Robertis A De, Guo L, Wynne KM (2015) Using dive behavior and active acoustics to assess prey use and partitioning by fin and humpback whales near Kodiak Island, Alaska. Mar Mammal Sci 31:255–278

Witteveen B, Straley J, Chenoweth E, Baker C, Barlow J, Matkin C, Gabriele C, Neilson J, Steel D, Ziegesar O von, Andrews A, Hirons A (2011) Using movements, genetics and trophic ecology to differentiate inshore from offshore aggregations of humpback whales in the Gulf of Alaska. Endanger Species Res 14:217–225

Wright A, Deak T, Parsons E (2009) Concerns related to chronic stress in marine mammals. Int Whal Commision 61:1–7

Wright AJ, Soto NA, Baldwin AL, Bateson M, Beale CM, Clark C, Deak T, Edwards EF, Fernández A, Godinho A, Hatch LT, Kakuschke A, Lusseau D, Martineau D, Romero ML, Weilgart LS, Wintle BA, Notarbartolo-di-Sciara G, Martin V (2007) Do marine mammals experience stress related to anthropogenic noise? Int J Comp Psychol 20:274–316

Wright DL, Witteveen B, Wynne K, Horstmann-Dehn L (2015) Evidence of two subaggregations of humpback whales on the Kodiak, Alaska, feeding ground revealed from stable isotope analysis. Mar Mammal Sci 31:1378–1400

Wright DL, Witteveen B, Wynne K, Horstmann-Dehn L (2016) Fine-scale spatial differences in humpback whale diet composition near Kodiak, Alaska. Mar Mammal Sci 32:1099–1114

Zerbini AN, Waite JM, Durban JW, LeDuc R, Dahlheim ME, Wade PR (2007) Estimating abundance of killer whales in the nearshore waters of the Gulf of Alaska and Aleutian Islands using line-transect sampling. Mar Biol 150:1033–1045

Zhang F, Bartels MJ, Geter DR, Carr MS, McClymount LE, Marino TA, Klecka GM (2009) Simultaneous quantitation of testosterone, estradiol, ethinyo estradiol, and 11-ketotestosterone in fathead minnow fish plasma by liquid chromatography/positive atmospheric pressure photoionization tandem mass spectrometry. Rapid Commun Mass Spectrom 23:3637–3646

Figures

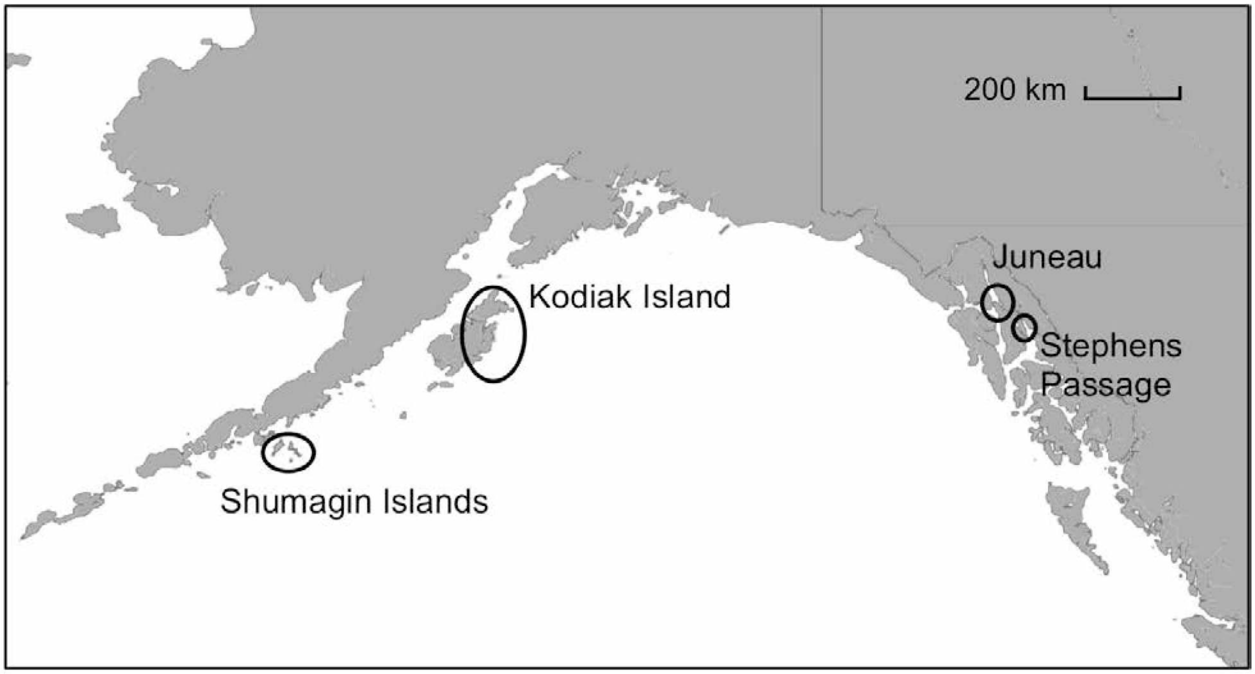

Figure 2.1: Locations of humpback whale biopsy sampling. Biopsies were used to measure cortisol concentrations in whales found in multiple areas in the Gulf of Alaska with differing vessel disturbance. Juneau, with high vessel exposure, was compared to control areas with far less vessel traffic: Stephens Passage in southeast Alaska, and Kodiak Island and Shumagin Islands in western Gulf of Alaska.

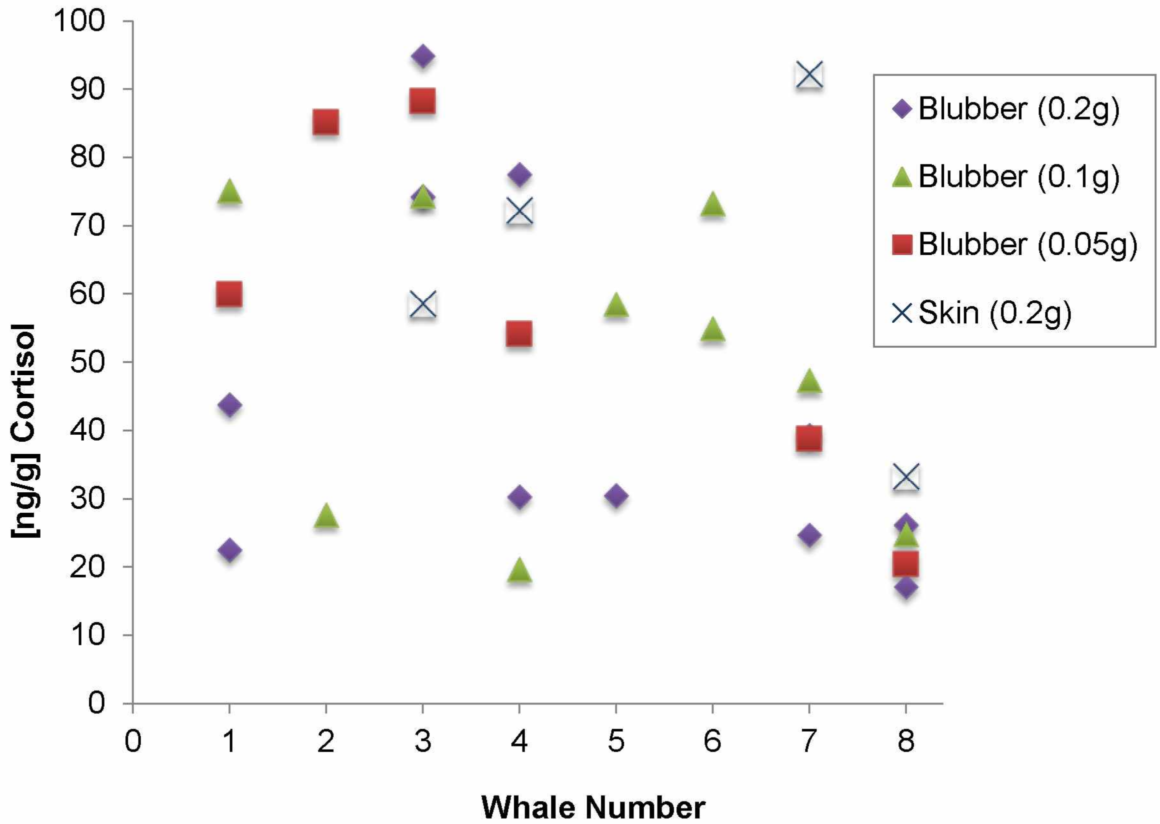

Figure 2.2: Cortisol concentration [ng/g] in samples of stranded humpback whales for 0.2 g skin samples, and blubber samples of various weights (0.2 g, 0.1 g, 0.05 g) displayed by individual whale (numbered on the x-axis).

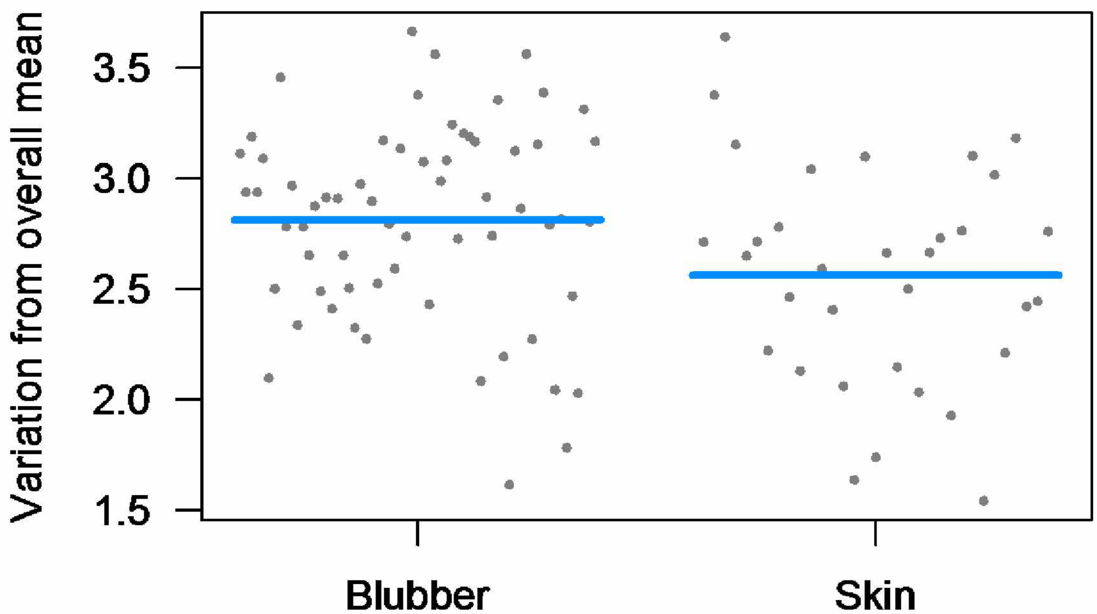

Figure 2.3: Variations from mean cortisol concentrations in humpback whale blubber *versus* skin from both stranded and biopsy samples. On average, there was no detectable difference in skin and blubber (*P*=0.12). Means (blue lines) and variation in cortisol concentration data (gray dots) from both blubber and skin are similar.

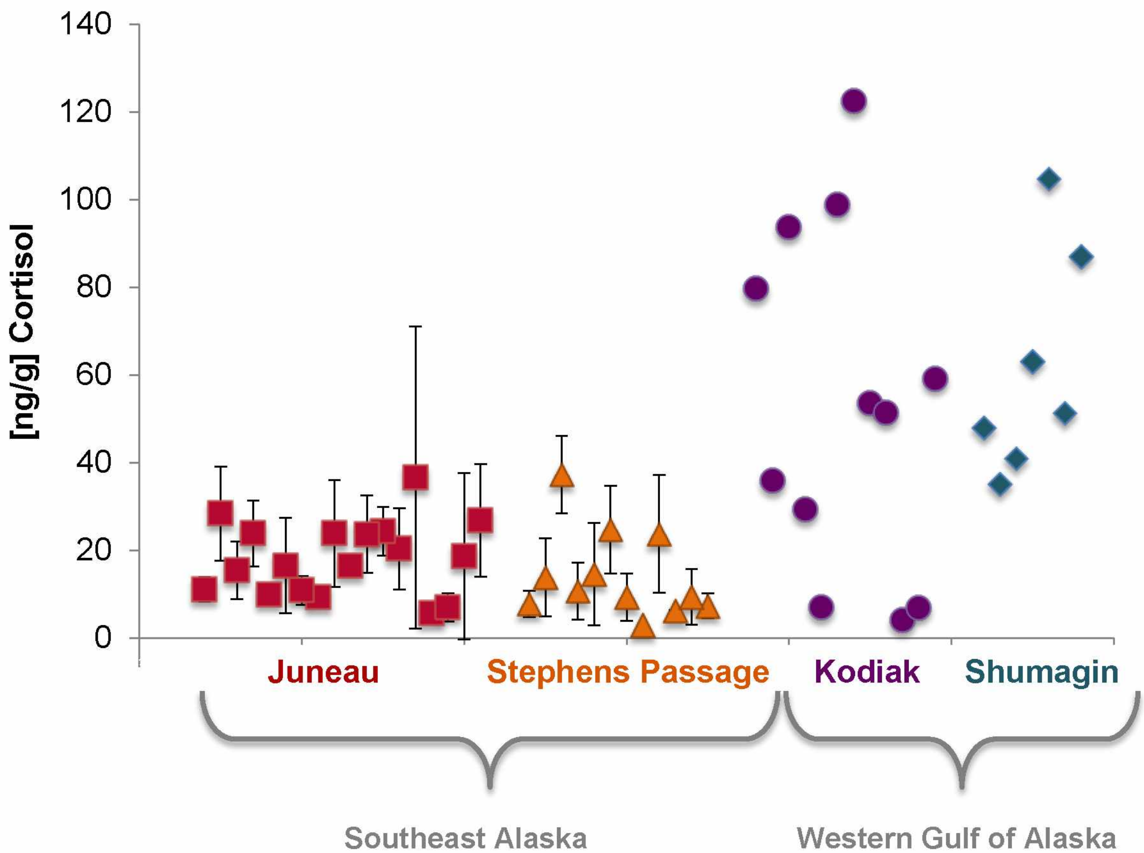

Figure 2.4: Cortisol concentration [ng/g] from blubber and skin biopsies in humpback whales by region. Blubber and skin cortisol concentration in Juneau area whales (exposed to high levels of vessel disturbance) compared with control areas with far less vessel traffic: Stephens Passage in Southeast Alaska, and Kodiak Island and Shumagin Islands in western Gulf of Alaska. Symbols mark the mean value and error bars represent two standard deviations and are present only for samples with enough excess tissue to analyze in duplicate. There was no significant difference in Juneau and Stephens Passage samples (t-test: $t=1.2$, $P=0.23$), but there is a highly significant difference in concentrations collected in Southeast Alaska and western Gulf of Alaska (t-test: $t=-5.0$ $P<0.001$).

Tables

Table 2.1: Summary of humpback whale biopsy samples analyzed for steroid hormones, including the area and years in which they were collected.

Area	# Whales Sampled	Collection Years
Experimental Area – Juneau	17 (including 1 skin only)	2014
Control 1 – Stephens Passage	11 (including 1 skin only)	2014
Control 2a – Kodiak Island	12	2010-2014
Control 2b – Shumagin Islands	7	2007-2012

Table 2.2: Summary of sighting history for humpback whales sampled in the Juneau tour area. The total number of sightings in 2014 season from surveys and data collected by whale-watching boats is given to demonstrate a proxy for exposure to whale-watching pressure. Sightings are also broken down by month to show how sightings were distributed throughout summer. Date sampled is provided to show the relationship between timing of sightings to sampling. There were no sightings of control area (Stephens Passage, Kodiak Island, Shumagin Islands) whales in the Juneau tour area during this study.

Whale ID	Total # Sightings	May	June	July	Aug	Sept	Oct	Date Biopsied
1879_calf_2011	**11**	0	0	0	3	7	1	9/10/14
UAF-20140910-365	**1**	0	0	0	0	1	0	9/10/14
2348*	**6**	0	0	1	2	3	0	9/10/14
1434	**21**	0	0	4	11	6	0	9/10/14
UAF-20140910-468	**4**	0	0	0	1	3	0	9/10/14
1443	**13**	0	2	5	5	1	0	9/10/14
2006	**18**	3	0	0	7	8	0	9/10/14
2171	**21**	0	2	0	9	9	1	9/12/14
1538	**51**	3	12	2	21	13	0	9/12/14
1820	**16**	0	0	6	4	6	0	9/12/14
1447	**37**	3	3	5	15	11	0	9/12/14
1879*	**23**	5	5	5	5	3	0	9/12/14
UAF-20140913-136	**1**	0	0	0	0	1	0	9/13/14

Table 2.2 (continued)

276	**1**	0	0	0	0	1	0	9/29/16
2258	**7**	0	0	0	2	5	0	9/29/16
1429	**1**	0	0	0	0	0	1	10/7/14
1612	**1**	0	0	0	0	0	1	10/7/14

* This whale was re-sighted in 2015 with a calf.

Table 2.3: Steroid hormone concentrations [ng/g] in all humpback whale blubber and skin samples, summarized by area. Values are means and 1SD is given in parentheses. *Estradiol values were excluded from analysis, because most (~60%) of the samples had concentrations below the detection threshold (~75 ng/g).

	Mean Cortisol [ng/g]	**Mean Testosterone [ng/g]**	**Mean Progesterone [ng/g]**	**Mean Estradiol [ng/g]***
Juneau	17.8 (11.7)	4.8 (4.3)	89.6 (72.7)	153.7 (38.2)
Stephens Passage	15.1 (11.7)	4.9 (3.8)	54.4 (40.3)	256.8 (150.1)
Kodiak Island	53.5 (39.1)	6.3 (3.5)	89.3 (22.6)	202.8 (85.4)
Shumagin Islands	61.5 (25.6)	6.2 (3.3)	128.3 (52.6)	121.5 (NA)

Table 2.4: Correlations between steroid hormone concentrations in humpback whale blubber and skin samples. Correlation values shown to the left (gray background) are Pearson correlation coefficients, and those to the right (white background) of the diagonal are Spearman rank correlation coefficients. Each coefficient is followed by a *P*-value, shown in parentheses. All correlations shown are significant (∝ < 0.05).

	Cortisol	**Testosterone**	**Progesterone**
Cortisol	---	0.35 (0.01)	0.44 (0.01)
Testosterone	0.45 (0.001)	---	0.36 (0.01)
Progesterone	0.30 (0.04)	0.32 (0.03)	---

Table 2.5: Tukey's honest significance difference test for humpback whale progesterone concentration by area. The only pair of regions with a significant difference (indicated with an asterisk) was Shumagin Islands and Stephens Passage.

	Q Statistic	*P*-value
Juneau *vs.* Stephens Passage	3.33	0.10
Juneau *vs.* Kodiak Island	0.07	0.90
Juneau *vs.* Shumagin Islands	2.99	0.16
Kodiak Island *vs.* Stephens Passage	2.98	0.17
Kodiak Island *vs.* Shumagin Islands	2.86	0.20
Shumagin Islands *vs.* Stephens Passage	5.42	<0.01*

Chapter 3: Juneau community perceptions of humpback whales and whale-watching tourism[1]

Abstract

After the cessation of large-scale whaling operations, human interest in whales shifted to viewing whales during boat-based tour excursions. Whale-watching tourism today is a multi-billion dollar industry widespread among the world's coastal ports. One such port, Juneau, Alaska, is home to a booming whale-watching industry that currently supports over 250,000 tourists each season and focuses on viewing humpback whales (*Megaptera novaeangliae*) that frequent the area in summer months. As the industry has grown, so too has concern for the welfare of humpback whales. The purpose of this study was to characterize the perceptions of Juneau community members toward humpback whales and Juneau's whale-watching industry. We used an online-based questionnaire and a chain-referral method to gather data on these perceptions. We found that most (69%) of our respondents are supportive of the industry, but still (up to 85%) had reservations about the way the industry operated. A majority of respondents perceived the industry to be too large, and expressed a need for regulating the number of participating vessels. A majority of respondents also expressed concerns for humpback whale welfare and support for humpback whale

[1] Teerlink, S. and L. Horstmann. Juneau community perceptions of humpback whales and whale-watching tourism. Submitted to *Tourism in the Marine Environments* (*In Review*).

conservation efforts. Some respondents reported perceived violation of regulations, while others expressed concern for humpback whales, even though they perceived whale-watching companies to be compliant with regulations. Interestingly, the predominant perceptions were not different between respondents who identified themselves as working in marine tourism and those that did not, suggesting broad agreement on conservation priorities and management implications for the Juneau whale-watching community.

Introduction

Human-whale interactions have shifted dramatically in recent decades. Whales were once exploited commercially for oil and baleen on a scale that brought many whale populations world-wide to the brink of extinction, including humpback whales (*Megaptera novaeangliae*) in the North Pacific Ocean (Gambell 1976; Johnson and Wolman 1984). After decades of harvest, several shifts in paradigm and policy worked to turn practices toward conserving the world's large whale species, rather than hunting them. These included several public campaigns and multiple legal protections on international, national, and local government levels (Gales et al. 2003; Orbach 2006). In 1966, the International Whaling Commission, the international organization responsible for the conservation of whale stocks, introduced a ban on the commercial harvest of North Pacific humpback whales (and later banned all commercial whaling in 1986). In 1970, the United States designated humpback whales as "endangered" under the Endangered Species Conservation Act (ESCA). When the ESCA was later replaced by the Endangered Species Act (ESA) in 1973, the humpback whale remained on the endangered species list under the new act (FWS 1970). They remained ESA listed globally until 2016 when they were separated into 14 distinct population segments (DPSs). Four of these DPSs are found in the North Pacific, including: Central America (listed as endangered), Mexico (now listed as threatened), Hawaii (no longer listed), and Western North Pacific (listed as endangered; NMFS 2016). An additional layer of protection was added with the passage of the Marine Mammal Protection Act (MMPA) in 1972. The MMPA affords protection from harvest for all marine mammals in U.S. waters, regardless of population status (with several exemptions for incidental takes and subsistence harvests; Baur et al. 1999; NMFS 2007).

After whaling harvests dropped off in the 1970's and most whale populations responded by increasing in abundance, whale-watching excursions began to gain popularity as a tourist attraction. By the early 1980's, whale-watching had become a full-fledged industry in a few select locations around the globe, accommodating several hundred thousand whale-watching passengers (Hoyt and Parsons 2014; Higham et al. 2015). Since its beginning, boat-based whale-watching tourism has spread to hundreds of ports and grown into a multi-billion dollar global industry (Cisneros-Montemayor et al. 2010; Cunningham et al. 2012; Higham et al. 2015). Many credit whale-watching tourism for shifting public support away from whale harvest and toward conservation by giving passengers first-hand exposure to marine life (Cunningham et al. 2012). Further, several analyses have demonstrated instances where whale-watching was more profitable and more sustainable than whaling (Hoyt and Hvenegaard 2002; Corkeron 2004; Cunningham et al. 2012).

Despite the obvious benefits to whale populations by shifting focus away from large-scale commercial harvest, whale-watching tourism also poses a threat to animal welfare. Increased vessel traffic around whales increases the probability of ship strike in whales subject to whale-watching tourism (Bezamat et al. 2014). Further, as our understanding of the complexities of whale behavior and physiology become better understood, there are growing concerns regarding the impact that disturbance from whale-watching vessels may have on wild whale populations (Bejder and Samuels 2003; Cressey 2014; Higham et al. 2014, 2015; Hoyt and Parsons 2014). Vessel presence, sound, and carbon emissions can have cumulative impacts on whales and cause changes in behavior and physiology that ultimately interfere with a whale's ability to forage, rest, and reproduce (Bejder and Samuels 2003). Several studies have documented short-term responses to vessel disturbance in humpback whales (*e.g.*, Avila et al. 2015; Dunlop 2016; Schaffar et al. 2009; Scheidat et al. 2004). In 2004, the National Marine Fisheries Service (NMFS) introduced Alaska-specific regulations to define restrictions in maneuvering around humpback whales in Alaska waters, including a 100 yard approach limit (NOAA 2004).

The port of Juneau, is a popular whale-watching hub in Alaska focused on viewing humpback whales. Whale-watching began in Juneau in 1994 and has been growing ever since (D. Ward, personal communication[2]). Juneau's current whale-watching industry is unique compared with other whale-watching industries around the world. Juneau's tour season runs from May – September and is largely comprised of cruise ship passengers. Roughly one quarter of Juneau's ~1 million seasonal tourists embark on whale-watching excursions departing out of Juneau's Auke Bay Harbor (Alaska Department of Commerce, Community, and Economic Development 2012). In 2016, 60 boats were operated by companies that advertise whale-watching excursions (including 11 vessels that focus primarily on charter fishing; S. Teerlink, unpublished data). Boats range from small, 6-passenger vessels, to larger 150-passenger vessels, and most boats will operate 2-3 trips each day (S. Teerlink, unpublished data). There are two factors that exacerbate the high vessel numbers and make Juneau's whale-watching tour experience different than other whale-watching industries around the world: 1) the local geography and 2) the common group feeding behavior of whales in this area.

First, Juneau is located in the Alexander Archipelago of Southeast Alaska, which is characterized by numerous islands, complex shorelines, and narrow waterways (Fig. 3.1). This prevents boats from spreading out and forces anglers, commercial fishermen, recreational boaters, tug and barges, cruise ships, and

[2] Doug Ward, Dolphin Jet Tours, December 2016.

other ship traffic to share the waterways with the marine tourism industry and the whales. Frequently, boats become congested in shoreline bottlenecks, particularly when whales are feeding in these areas. The local geography also prevents whale-watching vessels from spreading out to other whale groups, as they are often separated by islands, and boat operators are unable to spot other groups that are nearby.

Second, humpback whales near Juneau frequently engage in coordinated bubble net feeding. This behavior is generally limited to a few waterways in Southeast Alaska, but is especially common near Juneau (Sharpe 2001, S. Teerlink, unpublished data). The groups are generally made up of 5-15 whales that push fish to the water surface as they feed (Sharpe 2001), making for especially exciting whale-watching opportunities. Whale-watching operators rarely pass up the opportunity to view these bubble net feeding groups, even if it means that they need to share the space with, in some cases, up to 30 other vessels (S. Teerlink, unpublished data). The combination of narrow waterways and bubble net feeding groups gives Juneau's whale-watching industry a unique tendency toward excessive vessel crowding. As vessel crowding around whales has grown, so too have concerns for the welfare of whales being viewed, and the sustainability of the whale-watching industry.

Given the growing industry and endangered status of humpback whales, it is important to understand perceptions regarding sustainability of whale-watching in Juneau. Therefore, the objective of this study was to characterize the perceptions that Juneau residents have toward humpback whales and the local whale-watching industry. We evaluated differences in perceptions related to participation in the whale-watching industry and other factors. As is increasingly recognized, the best and most effective management decisions are made when stakeholder perspectives are taken into consideration (Simmons 1994; Prell 2009; Higham et al. 2014; Meynecke et al. 2016). With this study, we hope to provide policy makers with critical information about the community's concerns that need to be considered for effective management of Juneau's humpback whale population and the whale-watching tourism industry dependent on it.

Methods

Survey Design

The primary survey instrument was a self-administered, online questionnaire open from August 2015 – August 2016. A total of 106 respondents completed the survey. The survey frame was designated as Juneau residents with local on-the-water experience. There were approximately 32,000 residents of Juneau in 2015 (www.census.gov; accessed: 12/22/2016), though the proportion of residents with on-the-water experience is unknown. However, we roughly estimate a potential 10,000 Juneau residents with on-the-water experience, and 500 with experience working in marine tourism. A chain referral survey method was used, where respondents recommend others to participate (Bernard 2006). Initial contact was seeded through two venues: the Juneau Marine Naturalist Symposium, an event attended by many of Juneau's whale-watching participants, and the Juneau Maritime Festival, a community event attended by a broad user group, including recreational boaters and commercial fishermen. Respondents gained local marine experience through several methods, with most reporting participation in multiple categories (Fig. 3.2). Respondents were encouraged to participate if they had marine expereience near Juneau, but were allowed to self-determine and were not further screened for experience level. Because respondents were not selected randomly, and those participating were self-selecting, this survey is not a representative sample of the Juneau community. However, because we were interested in targeting residents that have on-the-water experience, we opted to use this non-representative sample.

Questionnaires were designed to collect information on Juneau residents' perceptions around five central themes: local humpback whale abundance; adaptability to future changes in humpback whale abundance; Juneau's whale-watching industry; participation in a new voluntary stewardship; education, and recognition program for wildlife viewing (Whale SENSE); and the proposed change in humpback whale status under the ESA. The majority of questions were closed-ended five-point Likert scale responses (strongly disagree, disagree, neutral, agree, strongly agree; Likert 1932). An open-ended question was asked at the end of each section, and at the end of the survey, to provide an opportunity for additional insight into aspects not previously covered or to further support closed-ended responses (See ‘Supplementary Material’ for a copy of the questionnaire).

Humpback Whale Abundance

Participants were queried about their perception of local humpback whale abundance trends. For reference, the North Pacific Basin estimates of humpback whale abundance indicate rapid population growth (Calambokidis et al. 2008). However, no longitudinal studies have documented changes in humpback whale abundance specific to the Juneau area. We asked participants to characterize trends in humpback whale abundance over the time of their marine experience.

Future Humpback Whale Abundance

We asked participants to indicate linkages between humpback whale abundance and their income, as well as their non-income wellbeing, in an effort to understand how participants might be influenced by future changes in local humpback whale abundance. Non-income wellbeing was used as a proxy for the (non-monetary) importance of humpback whale presence in terms of the intrinsic and/or recreational viewing value to residents.

Perceptions of Whale-Watching

We asked several questions targeted at understanding the perception of and support for Juneau's whale-watching industry. Questions were directed at understanding perceptions of impacts of whale-watching industry on humpback whales and the community itself, as well as perceptions toward programs to manage the number of vessels that can participate in this industry.

Whale SENSE Program

We included several questions targeted at understanding the influence that the new Whale SENSE program had on community perceptions toward whale-watching. The Whale SENSE program was first developed on the US East Coast through a partnership between NMFS's Greater Atlantic Region and Whale and Dolphin Conservation (WDC) non-profit (www.whalesense.org). The acronym, SENSE, stands for **S**tick to the regional whale-watching guidelines, **E**ducate naturalists, captains, and passengers to have SENSE while watching whales, **N**otify appropriate networks of whales in distress, **S**et an example for other boaters, **E**ncourage ocean stewardship. Whale SENSE is intended to promote responsible whale-watching and offers education and recognition to participants, who agree to higher tour standards. In response to community concerns about whale-watching practices, the NMFS Alaska Regional Office partnered with the Greater Atlantic Region and the WDC to extend the Whale

SENSE program to Alaska. The program was launched in 2015, and the majority of tour outfits in Juneau are currently enrolled. We offered a short description of the program to questionnaire respondents and asked several questions targeted at capturing the ways that perceptions toward whale-watching companies might change if they joined Whale SENSE.

ESA Status

The survey included questions to help us understand how the ESA status influenced concerns for local humpback whales. At the time of the survey, NMFS had responded to petitions to reclassify humpback whales under the ESA with a proposed rule (NOAA 2015). The proposal was to separate humpback whales into several Distinct Population Segments (DPSs) to then consider the ESA status of each of these smaller management units. In this management scenario, humpback whales would be managed by their low-latitude breeding locations, and the primary DPSs that are found in Southeast Alaska (Hawaii and Mexico) would no longer be listed under the ESA. Shortly after the close of the survey (September 8, 2016 and the survey closed August, 2016), NMFS released the Final Rule, where the Hawaii DPS was not listed under the ESA, and the Mexico DPS was listed as threatened under the ESA (NOAA 2016). Humpback whales in Southeast Alaska are comprised of 94% Hawaii DPS and 6% Mexico DPS according to Wade et al. (2016). We attempted to learn the impact that a change in ESA status would have, if any, on the perceptions that respondents had toward humpback whales and the whale-watching industry in Juneau.

Analysis

Likert-scale data were analyzed in aggregate (all responses pooled) and broken out into several groupings (Table 3.1) to better understand the factors that might influence perceptions. While all of these groupings were explored for all questions, most comparisons did not reveal differences between participant groups, so we limit our reporting to those groups that are most relevant to the specific question. Charter operators were combined with whale-watching companies to represent Juneau's "marine tourism," because charter operators frequently stop to watch whales and generally advertise this option when promoting their tours. Likert data were visualized using package "Likert" (Bryer and Speerschneider 2015) in program R (R Core Team 2016). To test for significant differences in responses between two participant groups, we used the Mann-Whitney significance test, which uses random resampling and does not assume normal distribution of data (Tallarida and Murray 1987). For groupings with more than two levels, the Kruskal-Wallis rank sum test was used (Hollander and Wolfe 1973).

Results

Humpback Whale Abundance

Humpback whales were perceived to be increasing in abundance by most respondents. We present these results with respondents broken out by length of Juneau residency (Table 3.1) to show how this perception changed with an increased duration of first-hand experience. As length of residency increased, so too did perception of increasing humpback whale abundance (Fig. 3.3). Responses indicating “Don’t know”, were removed from the analysis to allow comparisons between groups (Marsden and Wright 2010). Many respondents indicated they perceived local abundance of humpback whales to be increasing (either slowly or quickly). This is particularly notable in responses provided by long-time residents, who had greater timescales of experience for contrast.

Similar to the Likert-scale responses, open-ended written responses largely supported the notion that humpback whale abundance has been increasing. Of the 54 comments volunteered, 25 specifically mention increases, and only one expressed a perceived decline. Further, 12 of the 25 open-ended responses that mention an increase in humpback whale abundance also included reference to an increase in the number of calves seen in recent years.

Future Humpback Whale Abundance

Of the 106 respondents, 47% indicated that their income was linked to humpback whale abundance; 42% reported that their income would likely decrease if humpback whale abundance decreased, and 32% reported that their income would decrease, if humpback whale abundance became more variable. All others responded that changes in humpback abundance would not affect their income. Respondents also noted that their non-income wellbeing was linked to humpback whale abundance; 79% reported their non-income wellbeing would decrease if humpback whale abundance decreased, and 47% reported that their non-income wellbeing would decrease if humpback whale abundance became more fluctuant. All others responded that changes in humpback abundance would not affect their non-income wellbeing.

Perceptions of Whale-Watching

Generally, respondents were supportive of Juneau's whale-watching industry, but concerned about the impact it might have on Juneau's humpback whales (Fig. 3.4). Perceptions were generally similar among response groups. Respondents with higher income index values were significantly more likely to indicate support for the industry (P = <0.01). Further, respondents who indicated a perceived increase in humpback whale abundance differed from those that did not ("Abundance" in Table 3.1). If respondents believed abundance of humpback whales to be increasing, they were: more likely to express support for the whale-watching industry (W = 1834, $P = 0.0030$), less likely to express concern for whale-watching vessels deterring humpback whales from the area (W = 1076, $P = 0.035$), and less likely to perceive negative impacts to humpback whales from whale-watching (W = 1067, $P = 0.030$). Overall, approximately half of the responses expressed concern over negative impacts to humpback whales inflicted by the whale-watching industry, either in open-ended or closed-ended responses. However, some of these expressed through open-ended responses that any negative impacts to whales were outweighed by the positive conservation value gained through the experience passengers acquired through whale-watching. Respondents were split in their concern for the impact that whale-watching has on Juneau's docks and harbors. We did not see statistical differences in these responses dependent upon participation in the marine tourism industry or any other grouping (Appendix).

Most respondents expressed support for managing or limiting the number of vessels that can participate in whale-watching near Juneau. Results did not differ between respondents who worked in marine tourism and those who did not (Fig. 3.5) or any other grouping tested (Appendix).

Open-ended written responses further supported these results and provided more in-depth context. A total of 61 respondents included a short-answer response as follow-up to the questions in this section. Of these, 24 mention perceived humpback whale harassment. This was expressed as an alleged lack of compliance with regulations by whale-watching operators or by directly indicating concern for humpback whale welfare. Further, 22 responses specifically mention frustration (and in many cases even disgust) for the number of vessels participating in the industry and called for further regulation that would limit industry vessel numbers.

Whale SENSE Program

Responses indicated high level of support for the Whale SENSE program, with no differences between respondent groups (Fig. 3.6; Appendix). Of the 45 open-ended responses volunteered for this section, five praised the program for its educational elements and eight commented that Whale SENSE was a good “first step,” but six respondents also noted a need for more enforcement.

ESA Status

Respondent concern for the welfare of Juneau’s humpback whales and management of the whale-watching industry was not apparently linked to humpback whale ESA status, regardless of the respondent’s personal observations regarding humpback whale trends (Fig. 3.7). Rather, responses varied according to respondents’ Wellbeing Index. The higher their Wellbeing Index, the less likely respondents were to agree with the statements that a delisting under the ESA would cause them to be less concerned for humpback whales ($P = 0.019$) or that a delisting under the ESA would increase their support for industry growth ($P = 0.011$). Open-ended responses included several comments indicating that the ESA status should not change the way that Juneau's whale-watching industry is managed.

Discussion

The main purpose of this study was to characterize community perceptions toward humpback whales and Juneau's marine tourism industry in an effort to understand the issues, concerns, and recommendations of Juneau residents relating to whale-watching in a way that could be helpful to policy makers. Overall, we found that the majority of respondents were supportive of this industry, but had concerns for the impact that whale-watching vessels may have on humpback whales. The majority of respondents perceived an increase in humpback whale abundance near Juneau but still maintained overwhelming support for conservation of humpback whales and concern about harassment.

Humpback Whale Abundance

A large proportion (46%) of respondents reported increasing abundances, particularly longer-term residents (75% in residents of 16 or more years), suggesting that humpback whale abundance in the Juneau area has been on the rise. While we can't know to what extent these responses represent observations versus reporting on information from other sources, we believe that this is largely based on experience, given the details provided in the written response. Therefore, we believe that this indicates that humpback whale abundance near Juneau has mirrored that of the larger stock, i.e., recovering populations since the ban on commercial humpback whaling in the North Pacific in the 1960's (Calambokidis et al. 2008). While we did not ask a question that specifically addressed numbers of calves, the high number of unprompted reports (12) suggest that calf numbers are likely increasing. Increase in calf numbers is an indicator of favorable conditions for reproduction and signals continued population rise (Baker et al. 1987). An increase in humpback whale abundance has been documented for other areas in Southeast Alaska. For example, a longitudinal study in the nearby Glacier Bay National Park documented an increasing trend in whale abundance over recent decades (Neilson et al. 2015).

Future Humpback Whale Abundance

Most respondents indicated that they would be negatively affected by future declines in humpback whale abundance, or if humpback whale numbers near Juneau became more fluctuant and less predictable. Among the respondents who indicated that their income was positively correlated with humpback whale abundance and predictability, open-ended responses indicated various levels of confidence about resilience to this type of change. Some respondents suggested that declines or fluctuation in humpback whale abundance may impact their ability to offer a money back guarantee if whales are not sighted, but they were confident that they could continue to operate tours. Others expressed more concern for their livelihood and noted that without humpback whales, they would not have jobs. For example:

> *"The whales are the livelihood of many people that call Juneau home. They depend on the whale's presence to make a living while the tour boats [cruise ships] are in town."*

The marine tourism industry has substantial economic and intrinsic value in the Juneau community. No formal economic analysis of marine tourism revenue exists. However, based on the number of passengers who embark on whale-watching excursions (~250,000 per season) and a conservatively low $100 ticket price, this industry generates at least $25 million (US) in ticket sales each year. For reference, this is more than the ex-vessel value of all commercial fisheries in Juneau in 2015, which was $14.5 million (Commercial Fisheries Entry Commission 2016). The commercial fishing industry is often publicized as one of Juneau's most important economic generators. While the Juneau marine tourism industry is generally not as widely recognized for its economic contribution, it is clearly an important component of Juneau's economy, at least seasonally. Therefore, impacts to income from future declines or fluctuations in humpback whale abundance could potentially have broad economic consequence for the City and Borough of Juneau.

Four open-ended responses indicated concerns for increased risk of ship strike with increasing humpback whale abundance. The relationship between number of whales, the number of vessels, and speed of vessels has been investigated in several studies (*e.g.*, Bezamat et al. 2014; De Vos et al. 2016; Douglas et al. 2008; Harris et al. 2012; Neilson et al. 2012; Williams and Hara 2010). Naturally, as whale numbers or vessel numbers increase, so too does the risk of ship strike. Further, higher speeds further increase the risk of ship strike (Harris et al. 2012; Laist et al. 2014). Two comments specifically suggested speed restrictions around whales to prevent collisions. Still, the population-level threat from vessel strike is small for humpback whales, even in the face of focused whale-watching (Harris et al. 2012; Frink 2014).

Respondents generally indicated high levels of intrinsic value in having humpback whales near Juneau, and expressed that they would regret to see abundance decrease or become more fluctuant. For example, one response noted the following:

> *"It is a wonderful part of living in Juneau to be able to regularly see humpbacks in our waters. If their abundance decreased, it would decrease the value of living here, as the wildlife is one of the main reasons I choose to live in Juneau."*

Understanding and accounting for the intrinsic value that communities place on resources is an important component to a holistic management strategy (Prell 2009). For these reasons, we believe that managers should exercise a cautious approach and consider both the non-monetary value in addition to the economic aspect when managing humpback whales near Juneau.

Perceptions of Whale-Watching

Support for management of whale-watching vessel numbers and limiting growth of the whale-watching fleet was high (80%), and results did not vary by industry participation. Separate from the survey, one local whale-watching company owner related how he perceived the industry to be experiencing a "*tragedy of the commons"* in terms of the industry's growth. He felt most people agree that harbors and on-the-water operations are hindered by vessel crowding. However, there is high demand for whale-watching trips, and if companies do not purchase more boats to meet the demand, other companies will. Tour boat operators therefore generally opt to grow their fleet to stay competitive in the industry (B. Janes, personal communication, 2016). Respondents in this study clearly stated their support for limiting vessel numbers permitted to participate in whale-watching in the open-ended responses, regardless of their participation in the marine tourism industry. Some comments referenced concerns over how such a limited access program would be implemented, but most of the respondents indicated that this has become necessary. This perspective was further supported by a 2013 survey that found vessel overcrowding was the primary concern of whale-watching operators (Timm 2014).

The expressed support for limiting vessel numbers was argued from a variety of angles, including concerns for humpback whales, human safety, harbor crowding, local's quality of life, and the passenger experience. Several responses made mention of the number of vessels diminishing the experience of tourists, and thus the reputation of Juneau's whale-watching industry, for example:

> *"…the experience for the visitor is greatly diminished by the increase in whale-watching traffic. Most people come to Alaska to have a natural experience, or at least as close to one as they can get. The huge number of vessels means that many people end up disappointed, and that our whale-watching industry has become a tourist trap."*

In fact, surveys of whale-watching passengers in other regions around the world have identified that the absence of vessel crowding as a highly important factor to tour satisfaction (Avila-Foucat et al. 2013; Bentz et al. 2016; Buultjens et al. 2016). Further, in Banderas Bay, Mexico, passengers were less likely to repeat a whale-watching tour in the future, if they perceived vessel crowding (Avila-Foucat et al. 2013). Most passengers indicated that they would return to Banderas Bay for future whale-watching if vessel numbers around whales during their tour was two or less (Avila-Foucat et al. 2013), a far lower vessel density than is common in the Juneau area (5 - 30 vessels, depending on several factors).

There are several other models where tourism has been limited to preserve tourist experience. Research shows that there is a negative correlation between crowding and the experience of tourist (McCool and Lime 2001; Stewart and Cole 2001). One logical way to mitigate this is to limit access to popular tourist destinations, for example limited number of permits issued to Colorado River rafters and backcountry hikers in Grand Canyon National Park (Stewart and Cole 2001; Schwartz et al. 2012), or the limitation of numbers of divers on the Great Barrier Reef (Kenchington 1991). Limited access is less common for whale-watching tourism, but has been implemented in some areas; for example, New Zealand has a permit system in place to manage the number of operators (Meissner et al. 2015). Currently, there are no limited access programs for whale-watching in the United States.

Open-ended written responses highlighted an additional concern not directly addressed in closed-form questions; eight responses identified the disturbance that whale-watching vessels can present to residents. The impact of tourism activity on residents has been documented in many other areas (*e.g.*, Keogh 1990; Liu et al. 1987; Simmons 1994). Several responses noted frustration over the persistent vessel traffic, boat engine noise and loudspeaker noise that can be heard over long distances, boat wakes, and harbor congestion.

These disturbances were particularly relevant to respondents who identified as recreational boaters and oceanfront residents. One respondent noted:

> *"The industry is unchecked with more and more venturing into it. Not only are the whales likely impacted, other users (boaters/anglers) are being impacted by the non-stop water traffic…"*

In future studies, we recommend that perceptions of disturbance to residents be considered to effectively capture the ways in which in the community is affected by tourism.

Whale SENSE Program

Respondents generally supported the Whale SENSE program. Closed-form and open-ended comments indicated that respondents felt that the program is worthwhile and beneficial. However, several respondents indicated that they felt the Whale SENSE program was a good "first step," but many expressed a need for increased accountability and consequence to bring whale-watching vessel behavior up to an acceptable standard. Further, many comments indicated the necessity for an enforcement presence to hold vessel operators accountable for compliance with regulations. For example:

"One of the things needed is enforcement of the existing regulations. Whale SENSE is a great program, but it will do little to reduce the number of infractions. Better monitoring and increased fines would be more effective."

The implementation of a voluntary education and recognition stewardship program, such as Whale SENSE, may also be valuable to passengers. In passenger directed surveys, education and perceived sustainability has been highly valued (Lück 2015; Bentz et al. 2016). Further, in a study focused on Juneau's whale-watching participants, information disseminated on tours was found to be an effective way to communicate educational and conservation objectives (Lopez and Pearson 2016).

ESA Status

Responses to questions focusing on humpback whale ESA status clearly demonstrated that the ESA status did not dictate respondents' perspectives on humpback whale viewing practices, but did trigger concern for how they might be managed. Many respondents indicated that they were comfortable with the ESA change as other protections are in place (MMPA and Alaska Approach Regulations), while others expressed concern over any loss of protection. Respondents generally expressed concern for animal welfare and limiting potential harassment by vessel disturbance regardless of their perception of humpback whale population status. In other words, it appears that much of the concern for humpback whales is related to the intuitive objection to excessive vessel disturbance, not population-level threats. For example:

> *"Delisting should have no effect on Juneau whale-watching. Regardless of their official classification, whale-watching activities should first have the wellbeing of the whales in mind."*

> *"If they are delisted, it's a great teachable moment of what the ESA can do, but I don't think that warrants more whale-watching, they still need to be protected."*

Therefore, the ESA status (based on the risk of extinction of a species) does not change the way that respondents felt about potential harassment of humpback whales. Since this survey, several humpback whales DPSs have been reclassified and are no longer listed under the ESA. Southeast Alaska humpback whales are believed to be made up of 94% Hawaii DPS (no longer listed) and 6% Mexico DPS (remain listed as "threatened"), but because it is not possible to distinguish between DPSs on the feeding grounds, all humpback whales in Southeast Alaska continue to be protected under the ESA (NOAA 2016; Wade et al. 2016).

What is Harassment?

Harassment is difficult to define, and even more problematic to measure. The MMPA defines harassment as "…*any act of pursuit, torment, or annoyance that has the potential to injure a marine mammal or marine mammal stock in the wild or that has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns…*" This term has remained undefined under the ESA until December 2016, when NMFS released an interim guidance on interpreting the term "harass" as *"Create the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering."* Both definitions rely on subjective interpretation (*i.e.*, "potential" and "significantly", respectively), making these definitions difficult to implement. In practice, the inability to monitor underwater movement, and the difficulty in teasing apart potentially confounding factors makes determining harassment of marine mammals, at times, impossible. This is why the less subjective Alaska 100-yard approach rule is used by NMFS enforcement for monitoring whale watching activities in Alaska more often than rules that require interpreting humpback whale behavior (R. Marvelle, personal communication[3]).

In this study, we found that many respondents expressed concern over "harassment" of humpback whales. However, there was a clear division in the

---

[3] Robert Marvelle, PO BOX 21668, Juneau, Alaska, 99802-1668, Alaska Region, National Marine Fisheries Service. February 2017.

criteria that respondents used to define this. Some made comments in reference to perceived violation of NMFS regulations, including the Alaska 100-yard approach regulation. Several participants commented that boats were getting too close and that more enforcement was necessary to reduce harassment. However, without instruments (*e.g.*, theodolites, range finders, etc.), accurate estimations of distance cannot be made, particularly from afar. In a Hawaiian study, participants, regardless of experience, consistently underestimated distance over water between their vessel and whales (Baird and Burkhart 2000). While there was a high level of variability, on average, participants estimated nearly half the actual distance between the boat and whale (Baird and Burkhart 2000). Inaccuracies (overestimation) in observer's ability to judge distance over water adds an additional layer of complexity in management and response to reported violations to the Alaska humpback whale approach regulations. It is difficult to say if the reported concerns for vessels approaching whales too closely are truly a problem in practice, or if they are more of an issue in perception.

Other respondents put less emphasis on regulations and more weight on an intuitive concern for whale "harassment" based on their observations. Many respondents mentioned observations, where humpback whales presumably changed behavior linked to vessel disturbance. However, many of the respondents were simply citing a breach of an intuitive threshold of acceptable disturbance levels. These concerns were often described by referencing the high number of vessels in the area of whales, compounding vessel noise, and/or duration of vessel presence, but were not supported by evidence.

Disturbance from whale-watching vessels has been shown to change whale behavior in many other studies, for example, minke whales (*Balaenoptera acutorostrata*; Christiansen et al. 2014), sperm whales (*Physeter macrocephalus*; Cosentino 2016; Gannier and Marty 2015), killer whales (*Orcinus orca*; Jelinski et al. 2002; Trites and Bain 2000), Southern right whales (*Eubalaena australis*; Argüelles et al. 2016), and humpback whales (Corkeron 1995; Scheidat et al. 2004; Schaffar et al. 2009; Stamation et al. 2010; Avila et al. 2015). In these studies, short-term behavioral responses, such as vessel evasion and changes in dive time and respiratory rate, were correlated with whale-watching vessel presence. Therefore, the potential for vessel disturbance to be impacting whales near Juneau exists, though we require empirical research to objectively evaluate impacts of vessel disturbance on humpback whales specific to this area.

Several efforts to objectively assess impacts of vessel disturbance in Juneau area humpback whales are being undertaken, but this work is in the early stages. In one Juneau-based study of whale behavior (breathing and diving intervals) in the presence and absence of whale-watching vessels, mild short-term behavioral responses were documented (Peterson 2001). However, this work was done over 15 years ago, when whale-watching vessel numbers in Southeast Alaska were lower. In an ongoing study, land-based theodolites are being used to track whale behavior in the presence and absence of vessels to measure behavioral impacts of vessel traffic (H. Pearson, personal communication[4]). In a recent study measuring a potential marker of chronic stress response, blubber cortisol concentrations were not higher in Juneau area humpback whales compared with whales sampled from other areas in Alaska, suggesting that whales in the Juneau area may be habituated to vessel disturbance (Teerlink et al. *in review*). While these studies have provided important first steps and research is ongoing, we still lack a comprehensive understanding of affects from vessel disturbance and do not understand if vessel activity and noise in the Juneau area are negatively influencing humpback whales. We recommend that researchers continue to investigate vessel effects on humpback whales in this area to be able to objectively assess impacts and inform management decisions for a sustainable whale-watching industry.

Consensus on Conservation?

Humpback whale conservation was overwhelmingly supported by respondents, possibly because humpback whales are not currently perceived to be in direct competition with Juneau residents. Decades ago, many people supported whaling, in part, because of the perception that whales were in competition for fish resources (Corkeron 2014). But this perception has been largely dissociated, as we have gained a better understanding of whale prey and

[4] H. Pearson, University of Alaska Southeast, 2016.

ecosystem dynamics (Corkeron 2014). Humpback whales feed on herring (*Clupea pallasii*) and other small schooling fish and zooplankton, such as copepods and euphausiids (Johnson and Wolman 1984; Witteveen et al. 2008). Historically, a lucrative herring fishery existed near Juneau until the fishery crashed in the 1970s from overharvest. By 1983, the fishery was closed and has not re-opened due to persistent low herring biomass (Carls et al. 2008). Without this fishery, there is no direct competition between humpback whales and commercial fishers near Juneau. Further, our survey was not targeted at fishermen who we would expect to be more likely to express concerns related to competition (direct or indirect) and damaged gear from incidental interactions with humpback whales. These factors may help to explain the lack of respondent contention over conserving humpback whales, as is seen in many other wildlife management controversies. The classic example involves management of wolves (*Canis lupus*) in Yellowstone National Park, where there is a division between people who support culling wolves that are perceived to threaten local livestock, and those who support management conserving wolves in the park (Wilson 1997). In Alaska, there are similar resource-competition controversies for sperm whales and killer whales depredating on long line fisheries in the Gulf of Alaska (Peterson et al. 2013; Sigler et al. 2008) and Steller sea lions (*Eumetopias jubatus*) with fisheries of several different gear types (Dillingham et al. 2006). Similarly, sea otters (*Enhydra lutris*) in Southeast Alaska are increasing in abundance and range and are competing with humans for shellfish and other invertebrates (Carswell et al. 2015). In these cases, the perspectives on how conservatively these species should be managed are widely variable and hotly debated. Because we did not target fishermen and there does not appear to be a perception of competition with these predators, we see broad support for conserving humpback whales near Juneau.

Interestingly, in this study, there were very few differences in responses between respondent groups. In particular, there were very few significantly different responses between groups who identified as marine tourism participants and those who did not. This was evaluated in several ways (Tourism, Tourism 5+, and Income Index – see Table 3.1 and Appendix). This differs from the findings of Haralambopoulos and Pizam (1996), where residents of Pythagorion, Greece, who relied on tourism for income where much more likely to support tourism in their community. The largest differences in responses were between people who perceived an increasing trend in humpback whale abundance and those who reported humpback whales abundance in any other category. Respondents who perceived humpback whales as increasing were less likely to be concerned for humpback whale welfare and more supportive of tourism. However, it is important to emphasize that we did not have a representative sampling of Juneau residents. Further, we do not have a way of knowing if the self-selecting nature of this study somehow biased the respondent pool toward more conservation-minded residents. Selection bias is well documented, particularly when respondents are self-selecting (Heckman et al. 1998). In this study, it is possible that respondents who were more supportive of whale-watching or more conservation-minded were more motivated to participate in this study. However, we made every attempt in our survey design and respondent solicitation to avoid biasing our respondent pool in this way and have no way to measure this. The general consensus among residents, regardless of their participation in marine tourism industry in Juneau highlights the importance of incorporating community perceptions into management decisions. According to the results of this study, an assumption that residents would be divided and self-serving in their conservation and management concerns of humpback whales would be inaccurate for the Juneau marine tourism industry.

Conclusions

The purpose of this study was to characterize community perceptions toward humpback whales and the whale-watching industry in Juneau, Alaska. Respondents generally perceived humpback whale abundance to be increasing in the area and were supportive of Juneau's whale-watching industry. However, most respondents had reservations and concerns about the number of vessels that participate in the industry, and the impact that marine tourism vessels might have on humpback whales. Notably, the predominant perceptions did not change dependent upon whether the participants worked in marine tourism. In fact, many of the responses most critical of the whale-watching industry were from participants who identified themselves as working in the marine tourism industry. There was little controversy around general conservation of humpback whales, but there were differences in perceived threat of harassment by whale-watching vessels, and the need for additional regulation and enforcement. Stewardship standards did not appear to relate to respondents' perceptions of population trends or the ESA status of humpback whales, but instead were based on a more intuitive perception of harassment and empathy for humpback whales. Respondents generally favored efforts to increase standards in the industry for vessel behavior and on-board education. This study provides perceptions on a broad range of topics relevant to humpback whale management and demonstrates some of the ways that humpback whales and whale-watching in Juneau are important to the community. We suggest that this study is repeated after time to characterize changes in perceptions that may unfold with potential future changes in humpback whale abundance, human interactions, and marine tourism. We recommend that these results be taken into consideration when managing Juneau's whale-watching practices or other marine tourism industries, and that future research further evaluate this human-marine resource dynamic by monitoring humpback whale abundance, evaluating potential vessel disturbance, and understanding stakeholder perceptions and needs.

Acknowledgements

This project is funded by the National Science Foundation Marine Ecosystem Sustainability in the Arctic and Subarctic IGERT (Award #DGE-0801720) and the North Pacific Research Board (G8728). We gratefully acknowledge each of the respondents who took the time to complete this survey and share their knowledge, experience, perceptions, and suggestions. Thank-you to J. Sullivan for assistance with data visualization, and A. Beaudreau, F. Mueter, D. DeMaster, and B. Witteveen for their contributions to the study design and editorial comments on the manuscript. This project was approved by the University of Alaska Fairbanks Institutional Review Board (795896-1).

References Cited

Alaska Department of Commerce, Community, and Economic Development. (2012). Alaska Visitor Statistics Program VI.

Argüelles, M. B., Coscarella, M., Fazio, A., and Bertellotti, M. (2016). Impact of whale-watching on the short-term behavior of Southern right whales (*Eubalaena australis*) in Patagonia, Argentina. Tourism Management Perspectives, 18, 118–124. http://doi.org/10.1016/j.tmp.2016.02.002

Avila-Foucat, V. S., Vargas, A. S., Jordan, A. F., and Ramírez Flores, O. M. (2013). The impact of vessel crowding on the probability of tourists returning to whale watching in Banderas Bay, Mexico. Ocean and Coastal Management, 78, 12–17. http://doi.org/10.1016/j.ocecoaman.2013.03.002

Avila, I. C., Correa, L. M., and Parsons, E. C. M. (2015). Whale-watching activity in Bahía Málaga, on the Pacific coast of Colombia, and its effect on humpback whale (*Megaptera Novaeangliae*) behavior. Tourism in Marine Environments, 11(1), 19–32.

Baird, R. W., and Burkhart, S. M. (2000). Bias and variability in distance estimation on the water: Implications for the management of whale watching. International Whaling Commission Meeting, 1, 10.

Baker, S., Perry, A., and Herman, L. (1987). Reproductive histories of female humpback whales *Megaptera novaeangliae* in the North Pacific. Marine Ecology Progress Series, 41, 103–114.

Baur, D., Bean, M., and Gosliner, M. (1999). The laws governing marine mammal conservation in the United States. In R. R. Reeves (Ed.), Conservation and Management of Marine Mammals (pp. 48–86). Washington DC: Smithsonian Institutional Press.

Bejder, L., and Samuels, A. (2003). Evaluating the effects of nature-based tourism on cetaceans. In N. Gales, M. Hindell, and R. Kirkwood (Eds.), Fisheries, Tourism and Management issues (1st ed., pp. 229–256). Collingwood, Australia. Retrieved from http://whitelab.biology.dal.ca/lb/Bejder and Samuels 2003.pdf

Bentz, J., Lopes, F., Calado, H., and Dearden, P. (2016). Enhancing satisfaction and sustainable management : Whale watching in the Azores. Tourism Management, 54, 465–476. http://doi.org/10.1016/j.tourman.2015.11.016

Bernard, H. (2006). Research methods in anthropology: Qualitative and quantitative approaches (4th ed.). Lanham, Maryland: AltaMira Press.

Bezamat, C., Wedekin, L. L., and Simões-Lopes, P. C. (2014). Potential ship strikes and density of humpback whales in the Abrolhos Bank breeding ground, Brazil. Aquatic Conservation: Marine and Freshwater Ecosystems, (October 2013). http://doi.org/10.1002/aqc.2523

Bryer, J., and Speerschneider, K. (2015). Likert: Functions to analyze and visualize likert type items. Retrieved from https://cran.r-project.org/package=likert

Buultjens, J., Ratnayke, I., and Gnanapala, A. (2016). Whale watching in Sri Lanka: Perceptions of sustainability. Tourism Management Perspectives, 18, 125–133. http://doi.org/10.1016/j.tmp.2016.02.003

Calambokidis, J., Falcone, E. A., Quinn, T. J., Burdin, A. M., Phillip, J., Ford, J. K. B., … Maloney, N. (2008). SPLASH : Structure of populations, levels of abundance and status of humpback whales in the North Pacific. Final report for Contract AB133F-03-RP-00078, US Dept of Commerce Western Admin. Center, Seattle, WA. Seattle, WA. Retrieved from http://www.cascadiaresearch.org/SPLASH/SPLASH-contract-Report-May08.pdf

Carls, M. G., Johnson, S. W., Lindeberg, M. R., Neff, A. D., Harris, P. M., and Waples, R. (2008). Status review of Lynn Canal herring (*Clupea pallasii*).

Carswell, L. P., Speckman, S. G., and Gill, V. A. (2015). Shellfish fishery conflicts and perceptions of sea otters in California and Alaska. In S. E. Larson, J. L. Bodkin, and G. R. Van Blaricom (Eds.), Sea otter conservation (pp. 333–368). Elsevier Inc.

Christiansen, F., Rasmussen, M. H., and Lusseau, D. (2014). Inferring energy expenditure from respiration rates in minke whales to measure the effects of whale watching boat interactions. Journal of Experimental Marine Biology and Ecology, 459, 96–104. http://doi.org/10.1016/j.jembe.2014.05.014

Cisneros-Montemayor, A. M., Sumaila, R. U., Kaschner, K., and Pauly, D. (2010). The global potential for whale watching. Marine Policy, 34(6), 1273–1278.

Commercial Fisheries Entry Commission (2016) Online database query, www.cfec.state.ak.us/gpbycen/2015/110194.htm, Accessed: 12/8/2016.

Corkeron, P. J. (1995). Humpback whales (*Megaptera novaeangliae*) in Hervey Bay, Queensland: Behaviour and responses to whale-watching vessels. Canadian Journal of Zoology, 73(7), 1290–1299. http://doi.org/10.1139/z95-153

Corkeron, P. J. (2004). Whale watching, iconography, and marine conservation. Conservation Biology, 18(3), 847–849. http://doi.org/10.1111/j.1523-1739.2004.00255.x

Corkeron, P. J. (2014). Human attitudes and values: Tradition and transformation and zombies. In J. Highman, L. Bejder, and R. Williams (Eds.), Whale-watching: Sustainable tourism and ecosystem management (First, pp. 48–56). Cambridge: Cambridge University Press.

Cosentino, A. M. (2016). Effects of whale-watching vessels on adult male sperm whales off Andenes, Norway. Tourism in Marine Environments, 11(4), 215–227.

Cressey, S. (2014). Ecotourism rise hits whales. Nature, 512, 358.

Cunningham, P. A., Huijbens, E. H., and Wearing, S. L. (2012). From whaling to whale watching: Examining sustainability and cultural rhetoric. Journal of Sustainable Tourism, 20(1), 143–161. http://doi.org/10.1080/09669582.2011.632091

De Vos, A., Brownell, R. L., Tershy, B., and Croll, D. (2016). Anthropogenic threats and conservation needs of blue whales, *Balaenoptera musculus indica*, around Sri Lanka. Journal of Marine Biology, 2016. http://doi.org/10.1155/2016/8420846

Dillingham, P. W., Skalski, J. R., and Ryding, K. E. (2006). Fine-scale geographic interactions between Steller sea lion (*Eumetopias jubatus*) trends and local fisheries. Canadian Journal of Fisheries and Aquatic Sciences, 119, 107–119. http://doi.org/10.1139/F05-208

Douglas, A. B., Calambokidis, J., Raverty, S., Jeffries, S. J., Lambourn, D. M., and Norman, S. A. (2008). Incidence of ship strikes of large whales in Washington State. Journal of the Marine Biological Association of the United Kingdom, 88(6), 1121–1132. http://doi.org/10.1017/S0025315408000295

Dunlop, R. A. (2016). The effect of vessel noise on humpback whale, *Megaptera novaeangliae,* communication behaviour. Animal Behaviour, 111, 13–21. http://doi.org/10.1016/j.anbehav.2015.10.002

Frink, D. (2014). Whale watching: Tourism is least of cetaceans' problems. Nature, 514(7522), 305–305. http://doi.org/10.1038/514305c

FWS. (1970). Conservation of endangered species and other fish and wildlife. Federal Registry (Vol. 35).

Gales, N., Hindell, M., and Kirkwood, R. (2003). Marine Mammals; Fisheries, Tourism, and Management Issues. (N. Gales, M. Hindell, and R. Kirkwood, Eds.) (First Edit). Collingwood, Australia: CSIRO Publishing.

Gambell, R. (1976). World whale stocks. Mammal Review, 6(1), 41–53. http://doi.org/10.1111/j.1365-2907.1976.tb00200.x

Gannier, A., and Marty, G. (2015). Sperm whales ability to avoid approaching vessels is affected by sound reception in stratified waters. Marine Pollution Bulletin, 95(1), 283–288. http://doi.org/10.1016/j.marpolbul.2015.03.029

Haralambopoulos, N., and Pizam, A. (1996). Perceived impacts of tourism. Annals of Tourism Research, 23(3), 503–526. http://doi.org/10.1016/0160-7383(95)00075-5

Harris, K., Gende, S. M., Logsdon, M. G., and Klinger, T. (2012). Spatial pattern analysis of cruise ship-humpback whale interactions in and near Glacier Bay National Park, Alaska. Environmental Management, 49(1), 44–54. http://doi.org/10.1007/s00267-011-9754-9

Heckman, J. J., Ichimura, H., Smith, J., and Todd, P. (1998). Characterizing Selection Bias Using Experimental Data. Econometrica, 66(5), 1017–1098. http://doi.org/10.2307/2999630

Higham, J., Bejder, L., Allen, S. J., Corkeron, P. J., and Lusseau, D. (2015). Managing whale-watching as a non-lethal consumptive activity. Journal of Sustainable Tourism, 24(1), 73–90. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/09669582.2015.1062020

Higham, J., Bejder, L., and Williams, R. (2014). Tourism, cetaceans and sustainable development: Moving beyond simple binaries and intuitive assumptions. In J. Higham, L. Bejder, and R. Williams (Eds.), Whale-watching: Sustainable Tourism and Ecological Management.

Hollander, M., and Wolfe, D. A. (1973). Nonparametric Statistical Methods. New York, NY: John Wiley and Sons.

Hoyt, E., and Hvenegaard, G. T. (2002). A review of whale-watching and whaling. Coastal Management, (30), 381–399. http://doi.org/10.1080/08920750290027

Hoyt, E., and Parsons, E. C. M. (2014). The whale-watching industry: Historical development. In J. Higham, L. Bejder, and R. Williams (Eds.), Whale-watching: Sustainable tourism and ecosystem management (First, pp. 57–77). Cambridge: Cambridge University Press.

Jelinski, D. E., Krueger, C. C., and Duffus, D. A. (2002). Geostatistical analysis of interactions between killer whales (*Orcinus orca*) and recreational whale watching boats. Applied Geography, 22, 393–411.

Johnson, J. H., and Wolman, A. A. (1984). The humpback whale, *Megaptera novaeangliae*. Marine Fisheries Review, 46(4), 30–37. Retrieved from http://spo.nmfs.noaa.gov/mfr464/mfr4647.pdf

Kenchington, R. (1991). Tourism development in the Great Barrier Reef Marine Park. Ocean and Shoreline Management , 15, 57–78.

Keogh, B. (1990). Public participation in community tourism planning. Annals of Tourism Research, 17(3), 449–465. http://doi.org/10.1016/0160-7383(90)90009-G

Laist, D., Knowlton, A., and Pendleton, D. (2014). Effectiveness of mandatory vessel speed limits for protecting North Atlantic right whales. Endangered Species Research, 23(2), 133–147. http://doi.org/10.3354/esr00586

Likert, R. (1932). A technique for the measurement of attitudes. Archives of Psychology, 140, 1–55.

Liu, J. C., Sheldon, P. J., and Var, T. (1987). Resident perceptions of the environmental impacts of tourism. Annals of Tourism Research, 14, 17–37.

Lopez, G., and Pearson, H. C. (2016). Can whale watching be a conduit for spreading educational and conservation messages? A case study in Juneau, Alaska. Tourism in Marine Environments. http://doi.org/10.3727/154427316X14779456049821

Lück, M. (2015). Education on marine mammal tours – But what do tourists want to learn? Ocean and Coastal Management, 103, 25–33. http://doi.org/10.1016/j.ocecoaman.2014.11.002

Marsden, P. V., and Wright, J. D. (2010). Handbook of survey research. Emerald.

McCool, S. F., and Lime, D. W. (2001). Tourism carrying capacity: Tempting fantasy or useful reality? Journal of Sustainable Tourism, 9(5).

Meissner, A. M., Christiansen, F., Martinez, E., Pawley, M. D. M., Orams, M. B., and Stockin, K. A. (2015). Behavioural effects of tourism on oceanic common dolphins, *Delphinus sp.*, in New Zealand: The effects of markov analysis variations and current tour operator compliance with regulations. PLoS ONE, 10(1), e0116962. http://doi.org/10.1371/journal.pone.0116962

Meynecke, J. O., Richards, R., and Sahin, O. (2016). Whale watch or no watch: The Australian whale watching tourism industry and climate change. Regional Environmental Change, 1–12. http://doi.org/10.1007/s10113-016-1034-z

Neilson, J., Gabriele, C. M., and Vanselow, P. B. S. (2015). Humpback whale monitoring in Glacier Bay and adjacent waters 2014 annual progress report. Gustavus, Alaska.

Neilson, J. L., Gabriele, C. M., Jensen, A. S., Jackson, K., and Straley, J. M. (2012). Summary of reported whale-vessel collisions in Alaskan waters. Journal of Marine Biology, 2012, 1–18. http://doi.org/10.1155/2012/106282

NOAA. (2004). Regulations governing the approach to humpback whales in Alaska (Vol. 66 FR 29502). Retrieved from https://alaskafisheries.noaa.gov/sites/default/files/finalrules/humpbackapproachfr.pdf

NOAA. (2007). The marine mammal protection act of 1972 as amended 2007. Retrieved from http://www.nmfs.noaa.gov/pr/pdfs/laws/mmpa.pdf

NOAA. (2015). Endangered and threatened species: Identification of 14 distinct population segments of the humpback whale (*Megaptera novaeangliae*) and proposed revision of the species-wide listing (Vol. 80 FR 2230). Proposed Rule. Retrieved from https://federalregister.gov/a/2015-09010

NOAA. (2016). Endangered and threatened species; Identification of 14 distinct population segments of the humpback whale (*Megaptera novaeangliae*) and revision of species-wide listing (Vol. FR 81).

Orbach, M. K. (2006). Whaling, Law, and Culture. In J. A. Estes, D. P. DeMaster, D. F. Doak, T. M. Williams, and R. L. Brownell (Eds.), Whales, Whaling, and Ocean Ecosystems (pp. 373–376). Los Angeles: University of California Press.

Peterson, H. (2001). Whale behavioral responses and human perceptions: An assessment of humpback whales (*Megaptera novaeangliae*) and vessel activity near Juneau, Alaska. Thesis. Duke University.

Peterson, M. J., Mueter, F., Hanselman, D., Lunsford, C., and Matkin, C. (2013). Killer whale (*Orcinus orca*) depredation effects on catch rates of six groundfish species: Implications for commercial longline fisheries in Alaska. ICES Journal of Marine Science, 70(6), 1220–1232.

Prell, C. (2009). Stakeholder analysis and social network analysis in natural resource management. Society and Natural Resources, 22(9), 501–518.

R Core Team. (2016). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from https://www.r-project.org/

Schaffar, A., Madon, B., Garrigue, C., and Constantine, R. (2009). Avoidance of whale watching boats by humpback whales in their main breeding ground in New Caledonia. International Whaling Commission, SC/61/WW6, January, 9.

Scheidat, M., Castro, C., Gonzalez, J., and Williams, R. (2004). Behavioural responses of humpback whales (*Megaptera novaeangliae*) to whale watching boats near Isla de la Plata, Machalilla National Park, Ecuador. Journal of Cetacean Research and Management, 6(1), 63–68.

Schwartz, Z., Stewart, W., and Backlund, E. A. (2012). Visitation at capacity-constrained tourism destinations: Exploring revenue management at a national park. Tourism Management, 33(3), 500–508. http://doi.org/10.1016/j.tourman.2011.05.008

Sharpe, F. A. (2001). Social foraging of the southeast Alaskan humpback whale, *Megaptera novaeangliae*. Dissertation. Simon Fraser University.

Sigler, M. F., Lunsford, C. R., Straley, J. M., and Liddle, J. B. (2008). Sperm whale depredation of sablefish longline gear in the northeast Pacific Ocean. Marine Mammal Science, 24(1), 16–27.

Simmons, D. G. (1994). Community participation in tourism planning. Tourism Management, 15(2), 98–108. http://doi.org/10.1016/0261-5177(94)90003-5

Stamation, K. A., Croft, D. B., Shaughnessy, P. D., Waples, K. A., and Briggs, S. V. (2010). Behavioral responses of humpback whales (*Megaptera novaeangliae*) to whale-watching vessels on the southeastern coast of Australia. Marine Mammal Science, 26(1), 98–122. http://doi.org/10.1111/j.1748-7692.2009.00320.x

Stewart, W. P., and Cole, D. N. (2001). Number of encounters and experience quality in Grand Canyon Backcountry: Consistently negative and weak relationships. Journal of Leisure Research, 33(1), 106–120.

Tallarida, R. J., and Murray, R. B. (1987). Mann-Whitney Test. In Manual of pharmacologic calculations: with computer programs (pp. 149–153). New York, NY: Springer New York. http://doi.org/10.1007/978-1-4612-4974-0_46

Teerlink, S. F., Horstmann-Dehn, L., and Witteveen, B. H. (in review). Blubber and skin steroid hormone concentration to evaluate chronic stress response from whale-watching vessels in humpback whales near Juneau, Alaska. Endangered Species Research.

Timm, K. (2014). Nature-based tourism operator response to environmental change in Juneau, Alaska. Thesis. University of Alaska Fairbanks.

Trites, A. W., and Bain, D. E. (2000). Short- and long-term effects of whale watching on killer whales (*Orcinus orca*) in British Columbia. In IWC Workshop on the Long-Term Effects of Whale Watching. Adelaide, Australia. 10. Retrieved from ftp://envinet.npolar.no/Out/pdf/dagv/WhWatch-effects.pdf

Wade, P. R., Quinn, T. J., Barlow, J., Baker, C. S., Burdin, A. M., Calambokidis, J., … Yamaguchi, M. (2016). Estimates of abundance and migratory destination for North Pacific humpback whales in both summer feeding areas and winter mating and calving areas. Submitted to the Scientific Committee of the International Whaling Commission, June 2016, Bled, Slovenia.

Williams, R., and Hara, P. O. (2010). Modeling ship strike risk to fin, humpback and killer whales in British Columbia, Canada. Journal of Cetacean Research Management, 11(1), 1–8.

Wilson, M. A. (1997). The wolf in Yellowstone: Science, symbol, or politics? Deconstructing the conflict between environmentalism and wise use. Society and Natural Resources, 10(5), 453–468.

Witteveen, B. H., Foy, R. J., Wynne, K. M., and Tremblay, Y. (2008). Investigation of foraging habits and prey selection by humpback whales (*Megaptera novaeangliae*) using acoustic tags and concurrent fish surveys. Marine Mammal Science, 24(3), 516–534. http://doi.org/10.1111/j.1748-7692.2008.00193.x

Figures

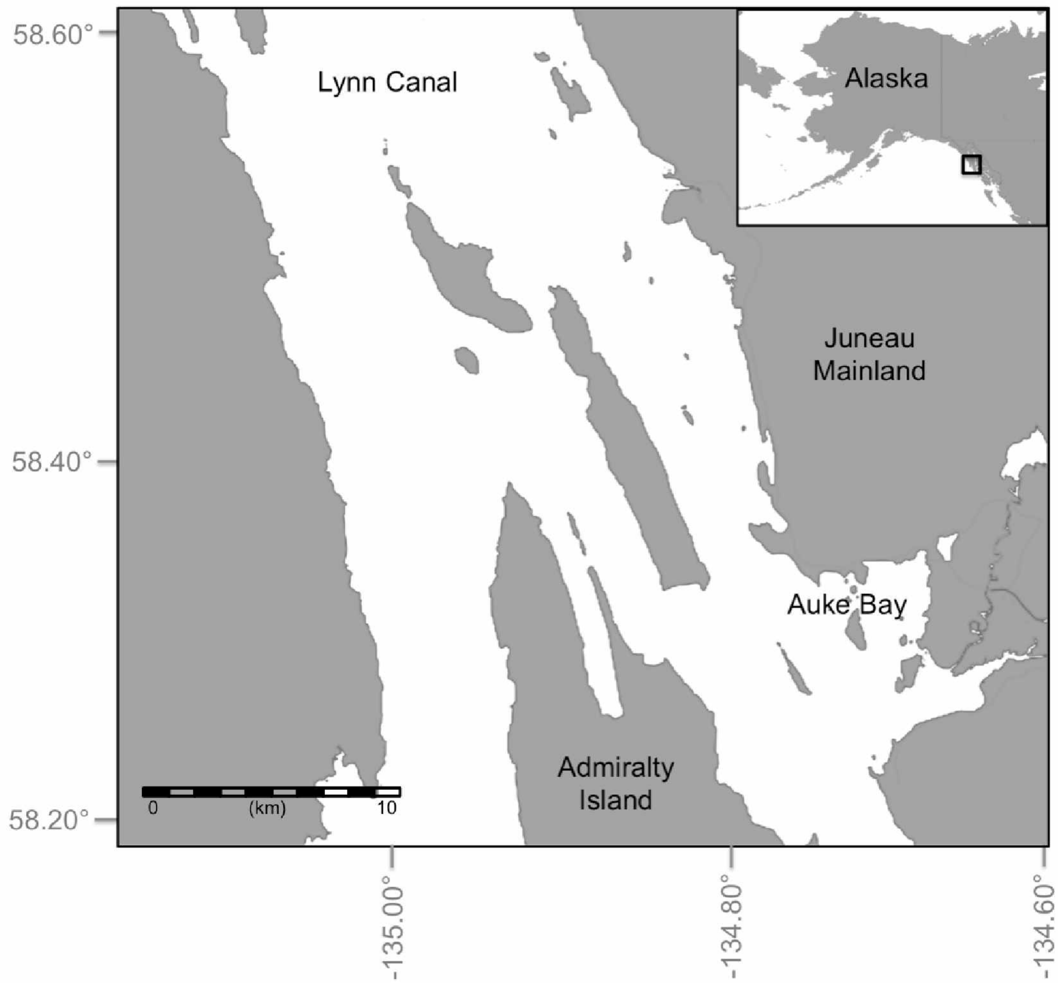

Figure 3.1: The primary whale-watching tour area for Juneau, Alaska. Most tours depart from and return to Auke Bay and run for 2-3 hours.

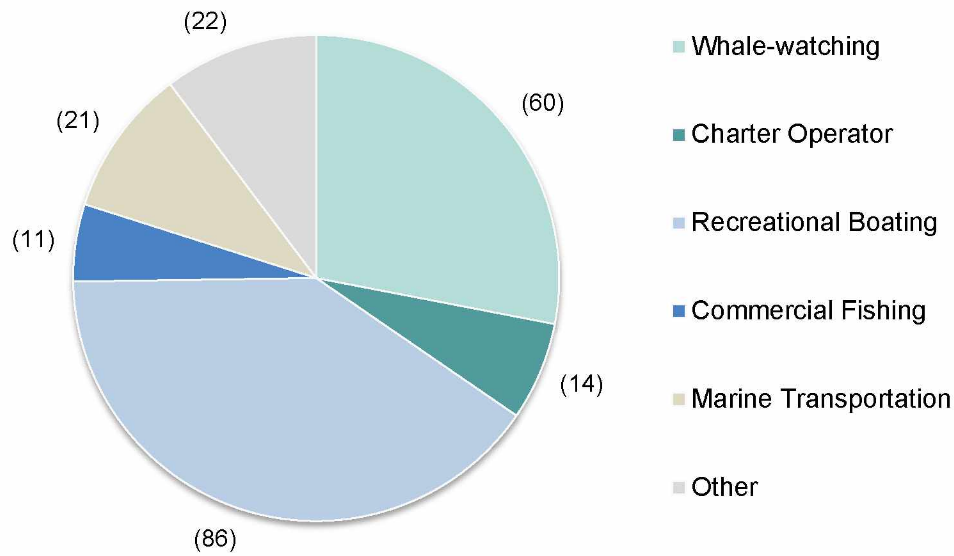

Figure 3.2: Marine experience of survey respondents in the Juneau, Alaska area. The number in parentheses indicates the number of participants with that form of experience. Participants were allowed to indicate multiple experience sources; therefore, the total number of responses and the number of participants are not equal.

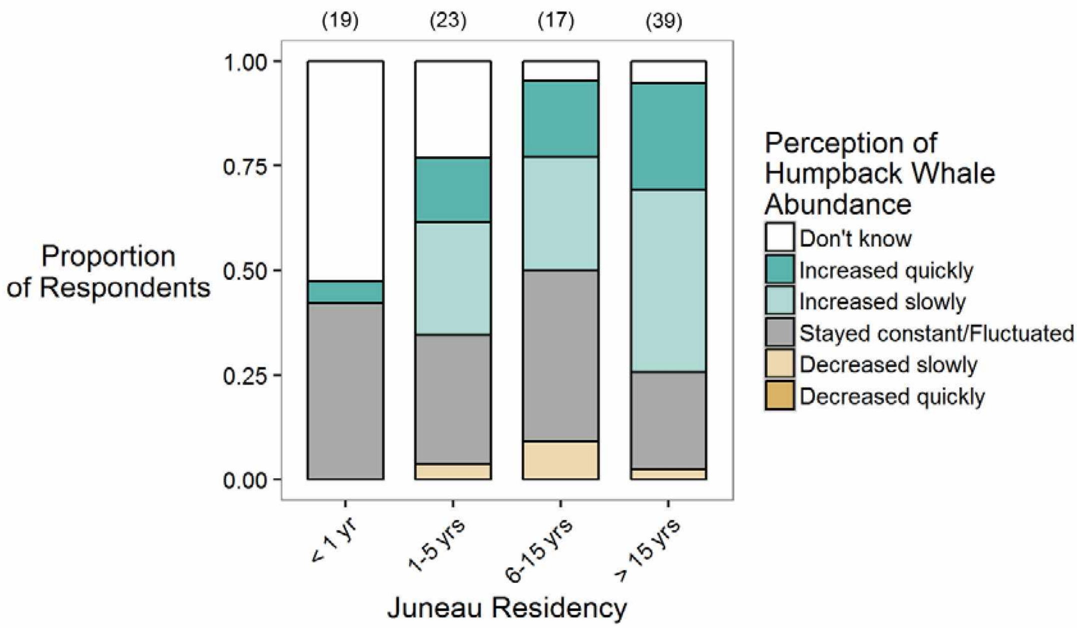

Figure 3.3: Respondent perceptions of humpback whale abundance trends near Juneau displayed by the length of time the participant has resided in Juneau. The numbers above each column shown in parentheses indicate the number of respondents, *n*, in each residency bracket. “Stayed constant” and “Fluctuated depending on year” were separate response options, but are pooled (Stayed constant/Fluctuated) to indicate responses that did not indicate a trend in abundance. “Decreased quickly” was a response option, but was not indicated by any respondent and is, therefore, not present in the graph.

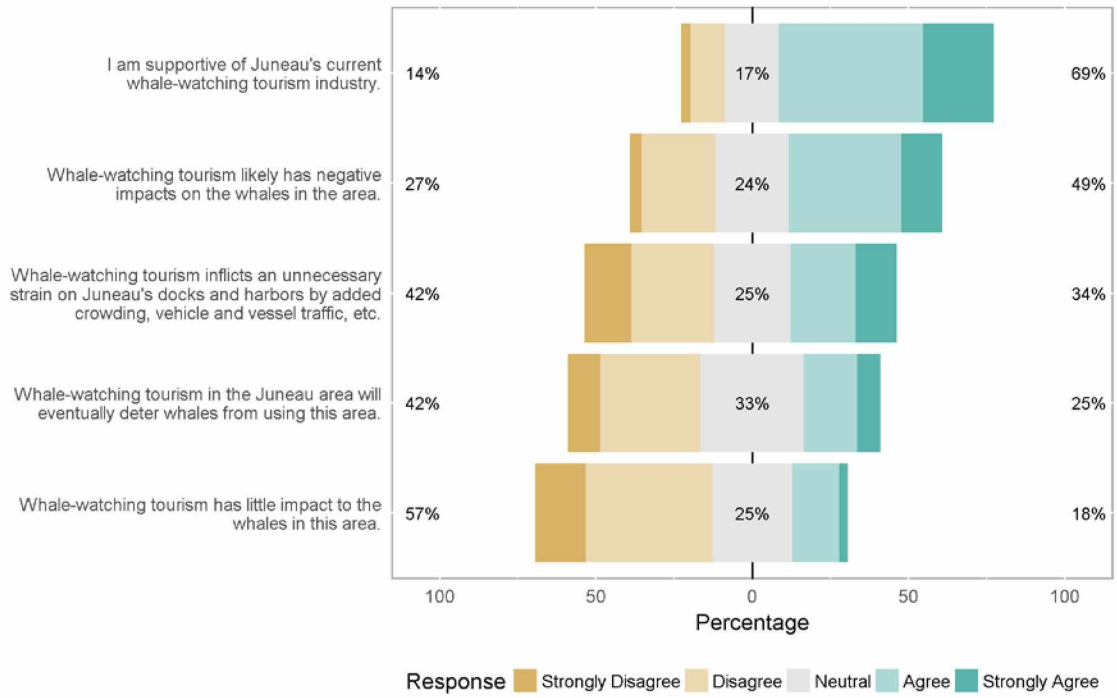

Figure 3.4: Likert-scale responses (n=106) to questions on perceptions of Juneau's whale-watching industry, and its impact on humpback whales and Juneau's docks and harbors.

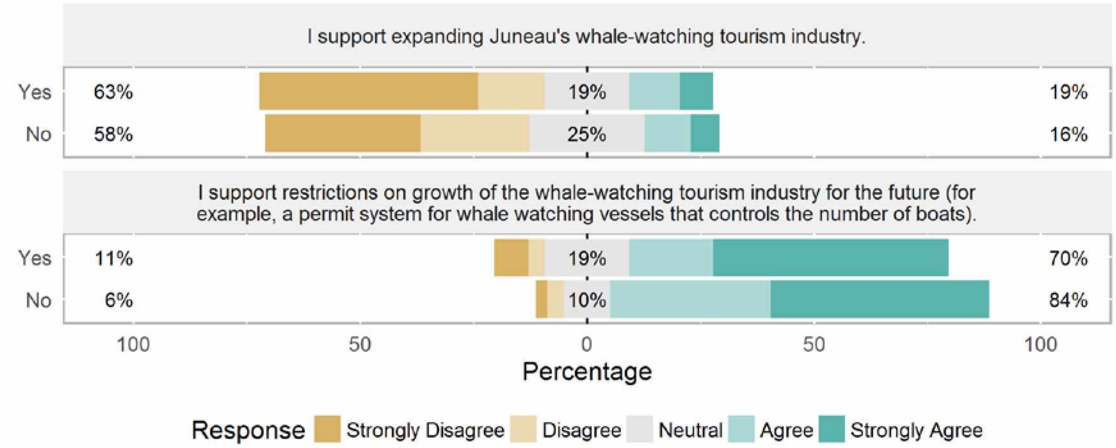

Figure 3.5: Survey responses (n=106) to questions relating to managing the number of vessels participating in Juneau's whale-watching industry. Participants are broken out by those vested in Juneau's marine tourism industry (Yes), and those that are not (No). Respondents were considered vested in Juneau's marine tourism industry, if they participated in whale-watching and/or charter fishing for 5 years or more.

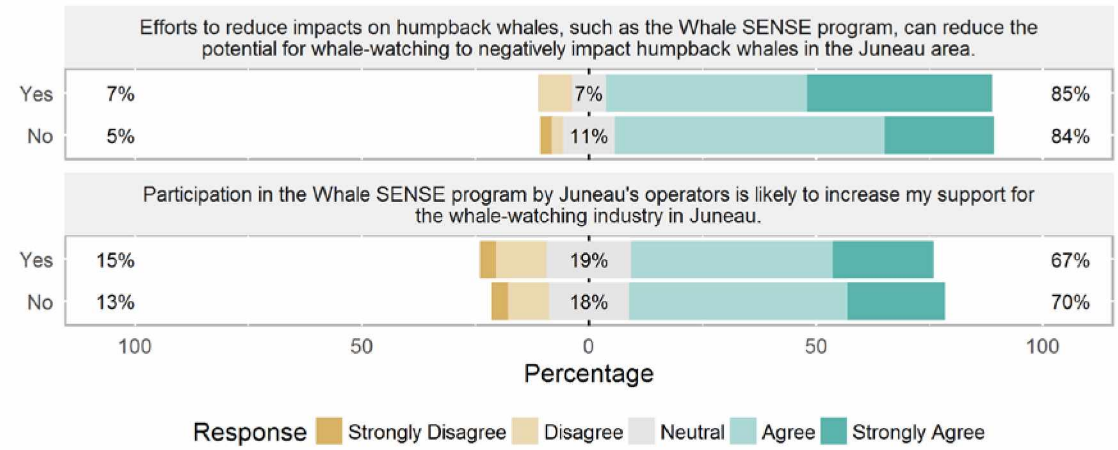

Figure 3.6: Responses (n=106) to questions related to the Whale SENSE program (NOAA program to promote responsible whale-watching). Respondents are broken out by those vested in the marine-based tourism industry (Yes), and those that are not (No). Participants were considered vested in marine-based tourism industry if they participated in whale-watching and/or charter fishing for 5 years or more.

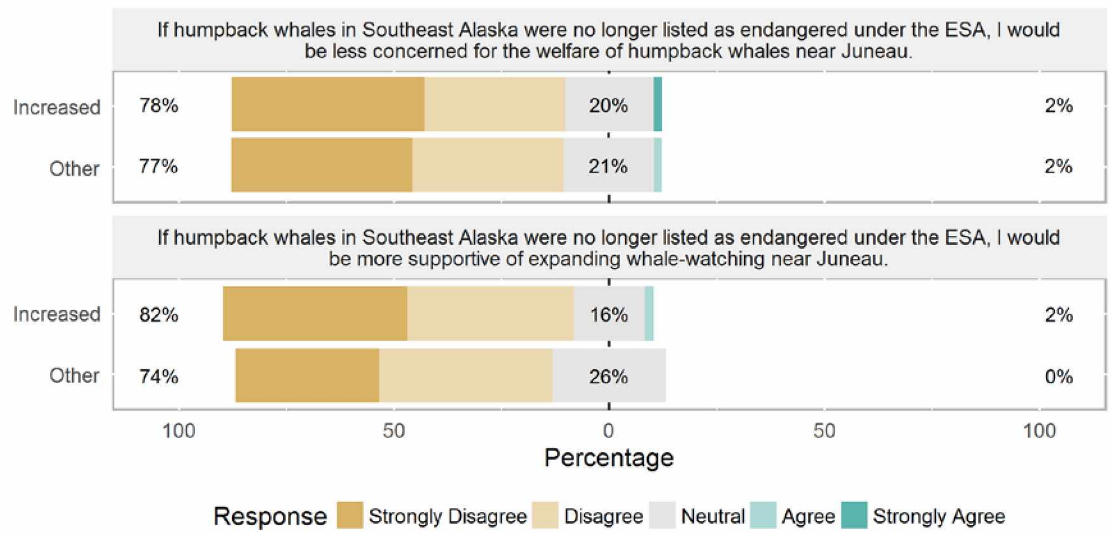

Figure 3.7: Likert-scale responses (n=106) to questions on how the status of humpback whales under the Endangered Species Act (ESA) would change their perceptions of Juneau's humpback whales and whale-watching industry. Responses are reported by those who indicated a perceived increase in humpback whale abundance (Increase), and those who did not (Other).

Tables

Table 3.1: Respondent groupings and descriptions. The number of respondents in each group is indicated in parentheses. All group assignments were made from responses indicated directly in the survey.

	Group 1		Group 2	
	Category	*Description*	*Category*	*Description*
Tourism	Yes (65)	Have any amount of experience working in Juneau's marine tourism industry	No (43)	Have no experience working in Juneau's marine tourism industry.
Tourism 5+	Yes (27)	Are vested into Juneau's marine tourism industry (5 or more years worked)	No (81)	Are not vested into Juneau's marine tourism industry (0-4 years worked)
Seasonal Status	Seasonal (27)	Reside in Juneau only seasonally	Year-round (79)	Reside in Juneau year-round

Table 3.1 (continued)

Abundance	Increasing (49)	Perceived humpback whale abundance near Juneau to be increasing (either slowly or quickly)	Other (57)	Perceived humpback whale abundance near Juneau to be decreasing (either slowly or quickly), constant, fluctuating, or didn't know
	Group 1	Group 2	Group 3	Group 4
Juneau Residency	1 yr or less (19)	1-5 yrs (23)	6-15 yrs (17)	16+ yrs (39)

Table 3.1 (continued)

Income Index	0 – no indication of a linkage between their income and humpback whale abundance trends (59)	1 – weak indication of a linkage between their income and humpback whale abundance trends (16)	2 – strong indication of a linkage between their income and humpback whale abundance trends (31)	N/A
Wellbeing Index	0 – no indication of a linkage between their non-income wellbeing and humpback whale abundance trends (22)	1 – weak indication of a linkage between their non-income wellbeing and humpback whale abundance trends (34)	2 – strong indication of a linkage between their non-income wellbeing and humpback whale abundance trends (50)	N/A

General Conclusions

The seasonal tourism industry is a large and growing economic driver in Juneau, Alaska, but little attention has been given to monitoring the primary attraction, humpback whales (*Megaptera novaeangliae*), identifying potential impacts, or considering community member perspectives in the management process. In this dissertation, I used tools from several scientific disciplines, including population dynamics, physiology, and applied social science, to present a holistic approach to addressing the management of Juneau's humpback whales and the whale-watching industry.

In Chapter 1, I evaluated citizen science as a tool for monitoring humpback whale populations from existing platforms of opportunity (i.e., whale-watching vessels). Data obtained by citizen scientists were compared to data collected from a dedicated survey platform, where bias specific to citizen science could be assessed. This approach illuminated the strengths and weaknesses of the citizen science dataset. Citizen science methodologies can potentially collect far more data than dedicated surveys, but tend toward an increased resight rate of whales in the study. With enough data, the effect of additional heterogeneity in sighting probability can be outweighed by the benefits of increased effort for estimation of humpback whale abundance; however, estimates of site fidelity and other measures of whale retention are susceptible to additional heterogeneity bias, regardless of effort. Citizen science programs offer additional, indirect benefits through outreach, education, and connection with key stakeholders.

Through this project, I have provided important information on how to use citizen science methods to engage the public in the scientific process, while collecting useful data for monitoring humpback whales in a limited funding environment. The results of this chapter are useful not only in establishing a long-term monitoring program for humpback whales near Juneau, but may have broad applications for other citizen science programs. Citizen science is increasingly being used to collect data efficiently, while engaging the public in the scientific process (Irwin 1995; Embling et al. 2015). I provided a framework for assessing the efficacy of these data and documented biases specific to these methodologies. Resources for cetacean monitoring are difficult to obtain, and with the recent change in ESA status of most humpback whale DPSs, it is likely that humpback whales will be a lower conservation priority and that funding will be even more difficult to secure. With limited funding for scientific research and rising global population and human development, potential risks to humpback whales are also increasing, and it is more important than ever to employ creative and efficient methodologies for data collection. I recommend that citizen science data collection be considered, but that dedicated surveys be used in tandem, where possible.

In Chapter 2, I evaluated stress response in humpback whales from the Juneau area that were exposed to whale-watching vessel traffic. Cortisol, progesterone, testosterone, and estradiol were measured in blubber biopsy samples and compared to biopsy samples collected from whales in different regions in Alaska with far less vessel traffic. This is the first study to look for long-term impacts to humpback whales from Juneau whale-watching vessels and to evaluate cortisol in humpback whale blubber.

This was also the first study to verify elevated progesterone levels in the blubber of a known pregnant female humpback whale. Clark et al. (2016) detected elevated progesterone levels that are presumed to be pregnant females, however, these authors did not have resighting data to verify these were indeed pregnant animals. While the sample size was small, the study furthers our understanding of humpback whale reproductive physiology and improves confidence in using biopsy samples to detect pregnancy. I suggest that future research use pregnancy detection from biopsy samples to measure reproductive rates and compare pregnancy rates to calving rates.

The results of this study also suggest that humpback whales targeted by Juneau's whale-watching fleet might be habituated to vessels. Humpback whales near Juneau did not have elevated cortisol in their blubber relative to humpback whales in areas with far less vessel traffic. Habituation is further supported by anecdotal observations of humpback whale behavior in this area. Humpback whales appear to continue to feed when whale-watching vessels are near, whereas, in other areas, they appear more skittish (personal observation). Understanding the role of habituation is important as this changes the way that vessel disturbance impacts humpback whales and other wildlife. Instead of soliciting a stress response that might encourage the animal to be more self-aware and evasive, a habituated animal has a higher threshold for stimuli and may remain in an area, largely ignoring vessels around them. I encourage future studies of humpback whales (and other marine wildlife) to consider habituation as a factor in vessel disturbance to appropriately characterize anthropogenic risks, such as ship strike.

While I did not find elevated cortisol associated with whale-watching vessel disturbance, this study did expose regional differences in cortisol. Biopsy samples from humpback whales in the western Gulf of Alaska (Kodiak Island and Shumagin Islands) had cortisol concentrations significantly higher than in biopsy samples of humpback whales in Southeast Alaska. Because hormone analysis of biopsy samples is an emerging field, we still lack an understanding of baseline concentrations and natural variability between individuals and DPSs. Interestingly, humpback whales from the western Gulf of Alaska are partly (0.5%; Wade et al. 2016) made up of the western North Pacific DPS, a population that remains endangered under the ESA. Both Southeast Alaska and western Gulf of Alaska humpback whales are mostly comprised of Hawaii DPS humpback whales, which are no longer ESA listed (94% and 89%, respectively; Wade et al. 2016). It is unknown if these regional differences are indicative of a stress response characteristic of the DPS and linked to population status, and I recommend that future studies consider genetic analysis to consider DPSs being sampled. Still, it is unknown if the regional differences in cortisol concentration documented are biologically significant as the relative changes are small compared to other comparisons demonstrated in marine mammals (*e.g.*, Trana et al. 2015; Kershaw and Hall 2016) Therefore, I recommend that future studies investigate regional differences in stress response, consider the factors that may be driving differences, and determine if these differences are biologically significant.

The methodologies and findings in this chapter are widely applicable. They demonstrate how biopsy samples can be used for measuring physiological parameters, and how these parameters help us to understand broader, population-level trends. Measuring steroid hormones in blubber is a relatively new scientific field, but has the potential to revolutionize conservation science and management, as it offers the ability to monitor several physiologic markers (*e.g.*, stress response, reproductive status, pregnancy rates, calf survival, calf loss, maturity) in free-ranging and elusive animals (Hunt and Moore 2013). Because humpbacks are easily identifiable, this technique also offers the opportunity to do long-term monitoring by repeat sampling to understand natural fluctuations or changes related to environmental factors (*e.g.*, climate change, seasonal changes, etc.). This project contributes to this emerging field by reporting baseline steroid hormone levels and demonstrating methods for evaluating stress response and *ad hoc* methods for determining the rough distributions of sex and reproductive status when these life history characteristics cannot be known prior to sampling.

In Chapter 3, I surveyed Juneau community members for their perceptions surrounding humpback whales, whale-watching tourism, and humpback whale management issues. I considered, among other things, respondents' participation in Juneau's marine tourism industry to evaluate if their perceptions changed dependent upon their involvement in the industry. However, I found surprising consensus among participants in this study, regardless of their connection to whale-watching industry. Collectively, respondents were concerned for humpback whale welfare and were supportive of the whale-watching industry; however, most participants agreed that the industry was in need of management and oversight to control the number of vessels and limit disturbance to humpback whales. This study offers an approach to solicit and summarize community perceptions as a way to include stakeholders in management decisions. These methods can be broadly applied to other resource management challenges in other areas. These methods may particularly useful in areas where whale-watching industries are growing. There are many areas where whale-watching industries are established and growing, but have not reached levels that present substantial contention for management (*e.g.*, Kenai Fjords and Ketchikan in Alaska). By developing regular monitoring, industry participation, and inviting community perspectives early, these tour industries are more likely to be sustainably managed and community supported.

In general, sufficient data are not always available in making management decisions and, by considering local knowledge and perspectives, particularly when data are limited, policy makers may be better able to manage resources sustainably. This has been shown to be the key to successful management in other areas, for example, in managing the subsistence harvest of bowhead whales (*Balaena mysticetes*) in northern Alaska, eastern Canada, and Chukotka, Russia. Reliable estimates of bowhead whale abundance did not exist at this time and scientists and managers lacked an understanding of their movements and distributions, especially in winter months. Scientists did not recognize at the time that bowhead whales are capable of traveling under ice and therefore were missing a substantial portion of the population in their surveys. Therefore, population estimates were poor until scientists collaborated with locals and corrected the survey design (Nunavut Wildlife 2000; Noongwook et al. 2007).

In this project, I generally rethought the way that stakeholders are invited into research. Outreach after the fact is not always satisfying to stakeholders, particularly with stakeholders who have appreciable first-hand experience (Irwin 1995; Johannes et al. 2000; Sousa et al. 2013). Understandably, it is common for local knowledge bearers to be frustrated with scientists over the focus, methods, and interpretation of their research, when their topic is perceived to be previously understood or misdirected. This disconnect conveys a message that science and local knowledge are mutually exclusive, and that local knowledge is not valuable to science. While the experience of local knowledge bearers may not always be in formal scientific surveys and methods, it can still provide stakeholders with an intimate knowledge of the topic (Irwin 1995; Johannes et al. 2000; Davis and Wagner 2003). In the case of humpback whales near Juneau, whale-watching operators have extensive knowledge about humpback whale trends, behavior, potential threats, and other factors. By inviting their participation through citizen science, we are recognizing their access and abilities and offering them a way share their experiences through standardized data. The partnerships formed through these types of projects are important on several levels. First, they help foster trust and working relationships that can be important for future collaborations and in implementing conservation measures. Further, they work to increase the scientific literacy of those involved and forces scientists out of the “ivory tower” into a more publically approachable and accountable role. By working with tour operators, this effort extends to include the onboard passengers. This type of exposure offers broad ripple effects for increasing general understanding of science to non-scientists, an essential educational element for encouraging critically thinking and evidence-based decisionmaking in the general public. Enlisting public participation is critical for environmental conservation; change is only possible through the will of the masses, and it is the scientists' role to work with the public further understanding of the complexity and interrelatedness of our ecosystems, and the impact that humans are having on them.

Recommendations for future studies

The research methods and results offered in this dissertation build on countless studies, observations, discoveries, knowledge bearers, and technologies. However, there is much more work to be done in these fields. I suggest that future studies consider new ways to measure the impacts (both positive and negative) of whale-watching on humpback whales and local communities. For instance, I recommend that a thorough economic analysis be done to fully document the economic contributions of whale-watching in Juneau and other whale-watching ports. Future studies should continue to investigate long-term impacts of vessel disturbance. In particular, it is important to understand the levels of vessel disturbance that are sustainable and what other environmental factors combine for the resources' sustainability to be threatened. Very little is known about the impact of vessel noise on marine wildlife; however, there is reason to believe that this noise could be masking natural sounds and communications that are important to feeding and reproduction (Wilson et al. 2004; Stimpert et al. 2011; Erbe et al. 2015). I urge future research to investigate the acoustic component of vessel disturbance from whale-watching vessels. Further, I advise that community members and tour passengers be surveyed on their experiences to better understand trade-offs in limiting vessel numbers in the whale-watching industry. This is relevant for any resource management challenge where crowding exists. I suggest that a holistic approach be taken when gathering information and implementing policy in resource management. The work presented here will contribute to management of human-whale interactions in Juneau, Alaska and elsewhere, and as a resource for other management challenges worldwide.

References Cited

Alaska Department of Commerce, Community and Economic Development (2012) Alaska Visitor Statistics Program VI

Buultjens J, Ratnayke I, Gnanapala A (2016) Whale watching in Sri Lanka: Perceptions of sustainability. Tour Manag Perspect 18:125–133

Calambokidis J, Falcone EA, Quinn TJ, Burdin AM, Phillip J, Ford JKB, Gabriele CM, Leduc R, Mattila D, Rojas-Bracho L, Straley JM, Taylor BL, Urbán JR, Weller D, Witteveen BH, Yamaguchi M, Bendlin A, Camacho D, Flynn K, Havron A, Huggins J, Maloney N (2008) SPLASH : Structure of populations, levels of abundance and status of humpback whales in the North Pacific. Final report for Contract AB133F-03-RP-00078, US Dept of Commerce Western Admin. Center, Seattle, WA

Clark CT, Fleming AH, Calambokidis J, Kellar NM, Allen CD, Catelani KN, Robbins M, Beaulieu NE, Steel DJ, Harvey JT (2016) Heavy with child? Pregnancy status and stable isotope ratios as determined from skin biopsies of humpback whales. Conserv Physiol 4:1–13

Davis A, Wagner JR (2003) Who knows? On the importance of identifying “experts” when researching local ecological knowledge. Hum Ecol 31:463–489

Duffus DA, Dearden P, Baird RW, Abrams PA, Dill LM, Brookshire DS, Eubanks LS, Randall A, Dekker D, Duffus DA, Dearden P, Rolston, H, Watkins WA (1993) Recreational use, valuation, and management, of killer whales (*Orcinus orca*) on Canada’s Pacific Coast. Environ Conserv 20:149

Embling CB, Walters AEM, Dolman SJ (2015) How much effort is enough? The power of citizen science to monitor trends in coastal cetacean species. Glob Ecol Conserv 3:867–877

Erbe C, Reichmuth C, Cunningham K, Lucke K, Dooling R (2015) Communication masking in marine mammals: A review and research strategy. Mar Pollut Bull 103:15–38

Goldbogen JA, Calambokidis J, Croll DA, McKenna MF, Oleson E, Potvin J, Pyenson ND, Schorr G, Shadwick RE, Tershy BR (2012) Scaling of lunge-feeding performance in rorqual whales: mass-specific energy expenditure increases with body size and progressively limits diving capacity. Funct Ecol 26:216–226

Higham J, Bejder L, Allen SJ, Corkeron PJ, Lusseau D (2015) Managing whale-watching as a non-lethal consumptive activity. J Sustain Tour 24:73-90

Hoyt E, Parsons ECM (2014) The whale-watching industry: Historical development. In: Higham J, Bejder L, Williams R (eds) Whale-watching: Sustainable tourism and ecosystem management, First. Cambridge University Press, Cambridge, p 57–77

Hunt K, Moore M (2013) Overcoming the challenges of studying conservation physiology in large whales: a review of available methods. Conserv Physiol 1:1–24

Irwin A (1995) Citizen science: A study of people, expertise, and sustainable development. Routledge, New York

Johannes RE, Freeman MMR, Hamilton RJ (2000) Ignore fishers' knowledge and miss the boat. 1:257–271

Johnson JH, Wolman AA (1984) The humpback whale, *Megaptera novaeangliae*. Mar Fish Rev 46:30–37

Jurasz CM, Jurasz VP (1979) Feeding modes of the humpback whale, *Megaptera novaeangliae*, in southeast Alaska. Sci Reports Whales Res Inst 31:69–83

Kershaw JL, Hall AJ (2016) Seasonal variation in harbour seal (*Phoca vitulina*) blubber cortisol - A novel indicator of physiological state? Sci Rep 6:21889

Leighton T, Finfer D, Grover E, White P (2007) An acoustical hypothesis for the spiral bubble nets of humpback whales, and the implications for whale feeding. Acoust Bull 32:17–21

Lusseau D, Bain DE, Williams R, Smith JC (2009) Vessel traffic disrupts the foraging behavior of southern resident killer whales *Orcinus orca*. Endanger Species Res 6:211–221

Neilson J, Gabriele CM, Vanselow PBS (2016) Humpback Whale Monitoring in Glacier Bay and Adjacent Waters 2015 Annual Progress Report. Gustavus, Alaska

Nemoto T (1957) Foods of baleen whales. Sci Reports Whales Res Inst 12:33–89

NOAA (2004) Regulations governing the approach to humpback whales in Alaska. 66 FR 105.

NOAA (2011) Protective Regulations for Killer Whales in the Northwest Region Under the Endangered Species Act and Marine Mammal Protection Act. 76 FR 2087

NOAA (2016) Endangered and threatened species; Identification of 14 distinct population segments of the humpback whale (*Megaptera novaeangliae*) and revision of species-wide listing. 81 FR 174

Noongwook G, Huntington HP, George JC (2007) Traditional knowledge of the bowhead whale (*Balaena mysticetus*) around St. Lawrence Island, Alaska. Arctic 60:47–54

Nunavut Wildlife (2000) Final report of the Inuit bowhead knowledge study. Nunavut Wildlife management board. Iqaluit, Nunavut

Sharpe FA (2001) Social foraging of the southeast Alaskan humpback whale, *Megaptera novaeangliae*. Dissertation. Simon Fraser University

Sousa MEM, Martins BML, Fernandes MEB (2013) Meeting the giants: The need for local ecological knowledge (LEK) as a tool for the participative management of manatees on Marajó Island, Brazilian Amazonian coast. Ocean Coast Manag 86:53–60

Stimpert AK, Au WWL, Parks SE, Hurst TP, Wiley DN (2011) Common humpback whale (*Megaptera novaeangliae*) sound types for passive acoustic monitoring. J Acoust Soc Am 129:476–482

Taylor RB, Morrison MA, Shears NT (2011) Establishing baselines for recovery in a marine reserve (Poor Knights Islands, New Zealand) using local ecological knowledge. Biol Conserv 144:3038–3046

Trana MR, Roth JD, Tomy GT, Anderson WG, Ferguson SH (2015) Increased blubber cortisol in ice-entrapped beluga whales (*Delphinapterus leucas*). Polar Biol:DOI 10.1007/s00300-015-1881-y

Trites AW, Bain DE (2000) Short- and long-term effects of whale watching on killer whales (*Orcinus orca*) in British Columbia. IWC Work Long-Term Effects Whale Watching Adelaide, Australia p 10

United States Census Bureau (2017) Online database query. http://www.census.gov/quickfacts/table/PST045215/02110; accessed January 2, 2017.

Wade PR, Quinn TJ, Barlow J, Baker CS, Burdin AM, Calambokidis J, Clapham JP, Falcone E, Ford JKB, Gabriele CM, Leduc R, Mattila DK, Rojas-Bracho L, Straley J, Taylor BL, Urbán RJ, Weller D, Witteveen BH, Yamaguchi M (2016) Estimates of abundance and migratory destination for North Pacific humpback whales in both summer feeding areas and winter mating and calving areas. Submitted to Sci Comm Int Whal Comm June 2016, Bled, Slovenia

Weinberg A, Bellows S, Ekster D (2002) Sustaining ecotourism: Insights and implications from two successful case studies. Soc Nat Resour 15:371–380

Wilson B, Batty RS, Dill LM (2004) Pacific and Atlantic herring produce burst pulse sounds. Proc R Soc Biol Sci 271:95-7

Witteveen BH, Foy RJ, Wynne KM, Tremblay Y (2008) Investigation of foraging habits and prey selection by humpback whales (*Megaptera novaeangliae*) using acoustic tags and concurrent fish surveys. Mar Mammal Sci 24:516–534

Zerbini AN, Clapham PJ, Wade PR (2010) Assessing plausible rates of population growth in humpback whales from life-history data. Mar Biol 157:1225–1236

Appendix

Mann-Whitney Test (2 levels)

Significant differences in data distributions between group levels are indicated in bold. Significant (α = 0.05) results are indicated with and asterisk and highly significant (α = 0.01) results are indicated with two asterisks.

	Tourism		Tourism 5+		Seasonal Status		Abundance	
	W	*P-value*	*W*	*P-value*	*W*	*P-value*	*W*	*P-value*
In your experience, humpback whale abundance in the Juneau area has: (*stayed constant, increased slowly, increased quickly, decreased slowly, decreased quickly, fluctuated dependent upon year, don't know*).[1]	849	0.53	640	0.099	553	0.32	NA	NA

[1] Perceived abundance trends were also used as respondent grouping. Therefore, responses to perceived abundance trends are not shown by this grouping (indicated as NA).

I am supportive of Juneau's current whale-watching tourism industry.	1101	0.083	817	0.054	1203	0.29	**1833**	[2]**0.0030****
Whale-watching tourism in the Juneau area will eventually deter whales from using this area.	1477	0.42	1215	0.26	980	0.52	**1076**	[3]**0.035***
Whale-watching tourism has little impact to the whales in this area.	1363	0.96	924	0.28	1078	0.93	1528	0.38
Whale-watching tourism likely has negative impacts on the whales in the area.	1613	0.084	1088	0.88	854	0.11	**1067**	[4]**0.030***
Whale-watching tourism inflicts an unnecessary strain on Juneau's docks and harbors by added crowding, vehicle and vessel traffic, etc.	1481	0.41	1182	0.40	816	0.063	1172	0.15

[2] If respondents perceived an increase in humpback whale abundance, they were more likely to “agree.”
[3] If respondents perceived an increase in humpback whale abundance, they were more likely to “agree.”
[4] Respondents who perceived an increase in humpback whale abundance were less likely to “agree.”

I support expanding Juneau's whale-watching tourism industry.	1224	0.38	1169	0.44	1094	0.84	1484	0.57
I support restrictions on growth of the whale-watching tourism industry for the future (for example, a permit system for whale-watching vessels that controls the number of boats).	1326	0.85	1108	0.75	1065	0.99	1432	0.81
Participation in the Whale SENSE program by Juneau's operators is likely to increase my support for the whale-watching industry in Juneau.	1376	0.89	1088	0.87	1262	0.13	1241	0.29
Efforts to reduce impacts on humpback whales, such as the Whale SENSE program, can reduce the potential for whale-watching to negatively impact humpback whales in the Juneau area.	1091	0.059	908	0.20	**1313**	[5]**0.047***	1280	0.41

[5] Respondents who were seasonal residents were more likely to “agree.”

If humpback whales in Southeast Alaska were no longer listed as endangered under the ESA, I would be less concerned for the welfare of humpback whales near Juneau.	**1655**	[6]**0.039***	[7]**1351**	**0.027***	1157	0.48	1365	0.83
If humpback whales in Southeast Alaska were no longer listed as endangered under the ESA, I would be more supportive of expanding whale-watching near Juneau.	1343	0.94	1115	0.71	1251	0.16	1232	0.27

[6] Respondents who had participated in marine tourism were less likely to "agree."
[7] Respondents who had participated in marine tourism for 5 or more years were less likely to "agree."

Kruskal-Wallis Test (> 2 levels)

Significant differences in data distributions between group levels are indicated in bold. Significant (**α** = 0.05) results are indicated with and asterisk and highly significant (**α** = 0.01) results are indicated with two asterisks.

	Juneau Residency (df = 4)		Income Index (df = 2)		Wellbeing Index (df = 2)	
	Statistic	*P-value*	*Statistic*	*P-value*	*Statistic*	*P-value*
In your experience, humpback whale abundance in the Juneau area has: (*stayed constant, increased slowly, increased quickly, decreased slowly, decreased quickly, fluctuated dependent upon year, don't know*).	8.8	0.066	1.7	0.42	0.8	0.68
I am supportive of Juneau's current whale-watching tourism industry.	2.7	0.62	**17.4**	[8]**0.000****	4.6	0.099

[8] The higher the respondents' income index, the more likely they were to "agree."

Whale-watching tourism in the Juneau area will eventually deter whales from using this area.	2.4	0.66	2.2	0.33	6.2	0.046
Whale-watching tourism has little impact to the whales in this area.	**11.6**	[9]**0.020**	0.90	0.64	2.6	0.27
Whale-watching tourism likely has negative impacts on the whales in the area.	3.9	0.42	5.9	0.053	2.1	0.35
Whale-watching tourism inflicts an unnecessary strain on Juneau's docks and harbors by added crowding, vehicle and vessel traffic, etc.	1.9	0.76	5.4	0.068	2.2	0.34
I support expanding Juneau's whale-watching tourism industry.	1.1	0.90	0.4	0.84	5.0	0.084
I support restrictions on growth of the whale-watching tourism industry for the future (for example, a permit	3.5	0.47	0.1	0.93	3.2	0.21

[9] The longer the respondents' residency, the more likely they were to "agree."

system for whale-watching vessels that controls the number of boats).						
Participation in the Whale SENSE program by Juneau's operators is likely to increase my support for the whale-watching industry in Juneau.	4.5	0.34	5.1	0.079	3.8	0.15
Efforts to reduce impacts on humpback whales, such as the Whale SENSE program, can reduce the potential for whale-watching to negatively impact humpback whales in the Juneau area.	5.1	0.28	7.4	0.25	1.0	0.60
If humpback whales in Southeast Alaska were no longer listed as endangered under the ESA, I would be less concerned for the welfare of humpback whales near Juneau.	5.4	0.25	2.4	0.30	**7.9**	[10]**0.019***

[10] The higher the respondents' wellbeing index, the more likely there were to "agree."

If humpback whales in Southeast Alaska were no longer listed as endangered under the ESA, I would be more supportive of expanding whale-watching near Juneau.	**11**	[11]**0.026***	1.5	0.48	[12]**9.0**	**0.011***

[11] The longer the respondents' residency, the less likely they were to "agree."
[12] The higher the respondents' wellbeing index, the less likely they were to "agree."